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JOURNAL

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CONTRIBUTIONS TO AGRONOMIC TERMINOLOGY.—1.

CARLETON R. BALL AND CHARLES V. PIPER,

U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

The function of language is to convey ideas. Unless the language is understood in the same way by writer and reader this function is not served and ideas are not transmitted exactly. Gregory makes the possession of a common language by teacher and learner one of the seven fundamental laws of teaching.

It is becoming increasingly evident that the terminology of agronomy is not always clear. The science has expanded rapidly in recent years and the number of workers has greatly multiplied. The definition and limitation of the terms used have been largely a matter of individual interpretation and preference. As a natural result there is some laxity in use and some confusion in meaning of many agronomic terms. This condition exists in other rapidly expanding subjects, as aeronautics, bacteriology, ecology, electrical engineering, and serum therapy.

The deficiencies of agricultural terminology are much older than the youthful science of agronomy. More than eighty years ago they were made the subject of comment as follows:[1]

> One of the many requisites for advancing the improvement of agriculture is a correct nomenclature, in which respect no other science or art is so deficient. There are few terms used in agriculture which are of universal acceptation, and many of them are used in senses so different as to cause the written instructions given by one farmer to be unintelligible to most others. And these objections do not apply merely to the hundreds (if not thousands) of provincial terms used by unlettered cultivators; for they are found more or less to

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[1] Ruffin, Edmund, Farmers' Register, 1834.

apply to the most correct and well informed authors. Indeed it cannot well be otherwise. Almost every term used in agriculture was at first provincial, or limited in its application to the practice of some particular district—and but few have been so extended as to be universally recognized in a single sense. If there should ever exist a general system of correspondence and concert among the agriculturists of the United States, one of the first operations ought certainly to be the adoption of some common signification of common agricultural terms.

The same difficulties appear to exist in the terminology and nomenclature of other sciences. The citation of a few examples noted during the past year will serve for illustration.

Speaking particularly of human geography, Lyons[2] writes:

> It is probable that some of the lack of precision which is to be found in this part of the subject is to be attributed to the want of precision in its terminology. For many things in human geography good technical terms are required, but these must be selected by those who have studied the type or phenomenon concerned and have a clear idea of the particular conditions which they desire to associate with the term; this is not the work of a committee of selection, but must grow out of the needs of the individual workers.

Dr. C. L. Shear recently discussed the status of the terminology of plant pathology in the following words:[3]

> There is at present a decided lack of accuracy and uniformity in the use of the various technical terms used in mycology and pathology. With the exception of the rusts the descriptive terms used have not been accurately defined and coordinated in accordance with our present knowledge.

At the twelfth annual meeting of the American Genetic Association held at Berkeley, Cal., in August, 1915, a committee of seven on nomenclature (terminology) was appointed "with the particular request that it consider suitable definitions of inbreeding and line-breeding and relieve the confusion which now attends the use of these two words."

Some progress has already been made in the matter of agronomic terminology. As long ago as 1911 Dr. J. G. Lipman[4] proposed a rather complete classificational terminology for soil bacteria, grouping them according to their physiological functions.

In the year 1910 the senior writer[5] discussed the subject, outlining

[2] Lyons, H. G., The Importance of Geographical Research, Science, n.s., 42: 595. October 29, 1915.

[3] Shear, C. L., The Relation of Mycology to Phytopathology (Presidential Address), Science, n.s., 41: 481. April 2, 1915.

[4] Lipman, J. G., Suggestions Concerning the Terminology of Soil Bacteria, Bot. Gazette, 51: 455-460. June, 1911.

[5] Ball, Carleton R., Technical Terms in Agronomy, Proc. Amer. Soc. Agron., 2: 86-93 (1910), 1911.

some of the present-day difficulties presented by the terminology of agronomy. Certain new terms were proposed and recommended for use. The causes of lack of clearness in agronomic terminology were set forth as follows (p. 86):

> Confusion in the use of technical terms in agronomy has arisen from two specific sources. First, the science is expanding so rapidly that old terms have been stretched to cover new or broadened uses. Second, new words and phrases have made their appearance in our agronomic literature from time to time, often without other definition than that afforded by their context. From their very nature, the dictionaries cannot keep abreast of this movement and there has been no general or authoritative textbook to serve either as a guide in approved usage or as the proverbial "horrible example" to be avoided. Agronomists have been too long conducting experiments and recording results in the language at hand to give thought to a clearing house for these verbal obligations.

The writers of this paper, as members of the Committee on Terminology of this Society, have had this matter under consideration for the past several years. During this period the use of various agronomic terms by different authors has been noted and new terms proposed by them or others have been catalogued.

The time now seems ripe to begin the publication of the data which have been accumulated. It is proposed to do this in serial form, the present paper being the first of the series. It is the intention to treat the subject by sections, defining and discussing the principal terms now in use, as well as the new ones proposed, or any suggested restrictions or changes in meaning of terms already in use.

In the present paper are discussed and defined terms relating to the operations of seeding and setting, and also those relating to the meadow and pasture industry. The terms as presented have been subjected to examination and revision by several agronomists. The arrangement is in groups of related terms, rather than alphabetical. Members of the Society and others who are interested in these subjects are asked to give these definitions careful examination, and to communicate to the authors any opinions they may care to express. The fullest criticism is invited. After this further discussion the official adoption of such terms as are generally agreed upon will be recommended to the Society.

PLANTING TERMS.

broadcast, *v. t.* To sow or scatter seed on the surface of the ground by hand or by machinery.

The original meaning is to cast abroad or scatter widely, referring to primitive methods of hand seeding. It applies also to seed sown with seeders of the Cahoon and wheelbarrow types. It properly applies likewise to sowing done through the spouts of drills or seeders when the furrow-opening devices are not used and the seed is allowed to drop on the surface of the seedbed.

From the verb is derived the adjective, *broadcast,* as a *broadcast* field or a *broadcast* crop; also the adverb, as sown *broadcast.*

crosscast, *v. t.* To broadcast in two directions, the second crossing the first and usually at right angles to it.

From the verb is derived the adjective *crosscast* and likewise the adverb, as sown *crosscast.*

crossdrill, *v. t.* To drill seed in two directions, the second crossing the first and usually at right angles to it. From the verb is had the adjective, *crossdrilled,* as a *crossdrilled* field, and the adverb, as sown *crossdrilled.*

drill, *n.* A machine for sowing seeds in rows in shallow furrows in the ground, as a *graindrill,* an *oniondrill.*

diskdrill, n. A drill or seeder provided with revolving disks to open the furrows for the reception of seed.

hoedrill, n. A drill or seeder provided with small, nearly vertical shovels or hoes to open furrows for the reception of seed. The shovels may be attached independently or as points on the lower ends of metal spouts or boots.

shoedrill, n. A drill or seeder having wedge-shaped, nearly horizontal shoes or runners, similar to those of a corndrill (planter) for opening furrows to receive seed.

pressdrill, n. A drill or seeder having small, heavy wheels attached behind to firm the soil in the furrows.

drill, *v. t.* To sow in shallow furrows, as to *drill* seed; to sow seed with a drill, as to *drill* a field.

This term applies to all seeding in shallow furrows, no matter how the operation is performed, as, for instance, opening the furrows and sowing the seed by hand; sowing with a garden-drill, a graindrill, a corndrill (planter), or a cottondrill. From this is derived the adjective *drilled,* as a *drilled* field, a *drilled* crop.

diskdrill, v. t. To sow or drill seed with a diskdrill. From this, the adjective, as a *diskdrilled* field.

hoedrill, v. t. To sow or drill seed with a hoedrill.

shoedrill, v. t. To sow or drill seed with a shoedrill.

pressdrill, v. t. To sow or drill seed with a pressdrill.

corndrill, *n.* A machine for sowing or drilling corn; a cornplanter.

cornplanter, *n.* Same as corndrill, which is the preferable term. See discussion under the term, *plant.* See also *checkrower.*

drillfurrow, *n.* A shallow furrow opened by the furrowing device of a drill, or by hand, for the reception of seed.

drillrow, *n.* A row of seeds placed in a drillfurrow; a row of plants growing in a drillfurrow.

check, *v. t.* To sow or plant so as to form squares; to space equally in both directions, as seeds in a breeding nursery or corn sown with a checkrower.

checkrow, *n.* A row of seeds sown, or plants growing, in checks; that is, spaced equally in both directions, as a row of corn sown with a checkrower.

checkrower, *n.* 1. An attachment to a corndrill (planter) by which it drops seeds at equal intervals so as to produce checkrows. 2. A corndrill (planter) equipped with a checkrower.

plant, *v. t.* To set or to sow.

The word *plant* is a general term which includes the placing of seeds or living plants or vegetative parts of plants in position for growth. For the placing of seeds the words *sow* and *seed* are preferable, while for the placing of plants or vegetative parts thereof the word *set* is to be preferred. The sowing of the seed of corn, cotton, beans, sorghum, etc., is commonly called *planting* because the machine used is called a *planter*.

The use of *sow* and *set* as limited above is advocated. It is recommended that the word *plant* be used only in a general sense, as, for example, what to *plant* for profit, the *planting* season, *planting* operations, etc., in which both sowing and setting are or may be included.

replant, *v. t.* To reset or resow.

transplant, *v. t.* To transset.

set, *v. t.* To put or place living plants or vegetative parts of plants in position for growth, as to *set* a tree, a seedling, a cutting, a bulb, or a tuber.

Machines have recently been developed for the setting of seedling trees, tobacco, cabbages, tomatoes, sweet potatoes, bulbs, tubers, etc. Such machines, commonly called *planters,* are more properly called *setters,* and the operation, *setting.*

reset, *v. t.* To set again, as a set crop which has perished, or a field in which such crop has perished.

transset, *v. t.* To move a living plant from one situation and set it in another.

seed, *v. t.* To sow seeds or spores by hand or by machine. Compare *broadcast, drill,* and *sow.*

seedage, *n.* The propagation of plants by sowing seeds or spores.

seeder, *n.* 1. A machine for sowing seeds, either broadcast or drilled. 2. A person who sows seeds.

sow (sō), *v. t.* To place seeds or spores in position for growth, by hand or machine.

sower (sō-er), *n.* A person who sows.

resow, *v. t.* To sow again; to reseed; as, to *resow* a crop where the seed has failed to germinate or the plants have been killed, or to *resow* a field where failure to germinate or killing of plants has occurred.

reseed, *v. t.* Same as resow.

space, *v. t.* To set or place objects so that they will be separated by spaces; to place at uniform distances, as seeds or plants in a row, or rows in a plat. For example, rows were *spaced* 24 inches and the seeds 12 inches, or, the rows had a 24-inch *spacing* and the seeds a 12-inch *spacing.* From this is derived the adjectival phrases, as widely *spaced* plants, closely *spaced* rows, etc. The commonly used expressions "wide rows," "narrow rows," etc., are to be avoided because inaccurate, since not the row itself but the space between rows or plants is wide or narrow, respectively.

space, *n.* The distance between objects, as seeds in a row or rows in a plat.

Meadow and Pasture Terms.

forage, *n.* Vegetable matter, fresh or preserved, utilized by man as food for animals.

hay, *n.* The herbage of comparatively fine-stemmed grasses or other plants cut and cured for forage.

brown hay. Hay prepared by stacking when half cured, on account of which it undergoes fermentation with heating, the resultant product being brown in color.

straw, *n.* The dried remnants of a fine-stemmed harvested crop from which the seed has been thrashed or otherwise removed.

fodder, *n.* Maize, sorghum, or similar coarse grasses dried whole for forage and therefore including the grain, if any. After the grain is removed the remainder is called stover.

pulled fodder. The leaves of maize or sorghum removed by hand from the standing plants and dried.

topped fodder. The tops of maize cut from the standing plants and dried.

stover, *n.* Fodder from which the grain has been removed; that is, the stems and leaves only.

leafage, *n.* Leaves, collectively; foliage.

herbage, *n.* Herbs, collectively, especially the aerial portion.

rootage, *n.* Roots, tubers, bulbs, or other underground parts of plants, collectively.

grass, *n.* A plant of the natural family Gramineæ or Poaceæ.

In agricultural usage the word grass is sometimes applied to any plant used for hay, including clovers, alfalfa, etc., in addition to true grasses. Such use of the word is objectionable because often confusing, and should be avoided.

legume, *n.* A plant of the natural family Leguminosæ.

rush, *n.* A plant of the natural family Juncaceæ.

sedge, *n.* A plant of the natural family Cyperaceæ and especially of the genus Carex.

pulse, *n.* Leguminous plants or their seeds; mostly used in a collective sense.

pasture, *n.* A field or area of land covered with grass or other herbaceous forage plants and used for grazing animals.

permanent pasture. A pasture of perennial or of self-seeding annual plants which is kept for grazing indefinitely. In many cases such pastures are seldom or never plowed.

temporary pasture. A pasture used for grazing during a short period, not more than one crop season.

rotation pasture. A pasture of a few years' lay, usually only two or three, then plowed for other crops.

tame pasture. A pasture covered with cultivated plants for grazing.

native, wild, or natural pasture. An area covered with native plants useful for grazing; when extensive, such an area is called a *range.*

pasture succession. A series of grazing crops arranged in definite succession.

pasture, *v. t. & i.* To graze.

pasturage, *n.* The feed produced on a pasture or range.

pasturer, *n.* A person who pastures animals.

graze, *v. i.* 1. To supply pasturage to animals. 2. To pasture a field.

overgraze. To graze so heavily that the plants are injured or destroyed.

undergraze. To graze so lightly that much available feed is not eaten.

closegraze. To graze so that the herbage is kept short but the plants not injured.

browse, *v. i.* To feed on the shoots of woody plants.

browse, *v. t.* To bite off and eat the leaves and twigs of woody plants.

browse, *n.* Leaves and twigs of woody plants eaten by animals.

trample, *v. t.* To crush plants or to compact the soil by the feet of animals; to tread underfoot.

range, *n.* An extensive area of natural pasture land; if fenced, it is called a *closed range;* otherwise, an *open range.*

supportage, *n.* The carrying capacity of a pasture as indicated by the number of animals of a particular kind that a unit of area will support for a definite period.

turf, *n.* The upper stratum of soil filled with the roots and stems of low-growing living plants, especially grasses.

sod, *n.* 1. Turf. 2. Turned or plowed meadow or pasture land.

sward, *n.* Turf, especially an expanse kept closely clipped.

stock, *n.* Domestic animals, in a collective sense; livestock.

ranch, *n.* A tract of land, especially native pasture, used mainly or wholly for raising and grazing domestic animals.

ranchman, *n.* A person who conducts a ranch; a rancher.

rancher, *n.* A ranchman.

cattleman, *n.* The owner or manager of a cattle ranch.

sheepman, *n.* The owner or manager of a sheep ranch.

shepherd, *n.* A man employed to care for sheep; on western range lands commonly called a *sheep herder.*

grazier, *n.* A person who makes a business of grazing animals.

meadow, *n.* A field or area covered with fine-stemmed forage plants, wholly or mainly perennial and used to produce hay.

The terms *permanent, rotation* and *temporary* are used with meadows as with pastures.

hayfield, *n.* A field used to produce hay.

grassland, *n.* Land covered wholly or mainly with grasses.

lea, *n.* Arable land laid down into meadow or pasture; also written *ley.*

math, *n.* The crop of mowed herbage as it lies in the field; a mowing.

aftermath, *n.* The second, shorter growth of meadow plants the same season after the main crop has been mowed; rowen; lattermath.

aftergrass, *n.* Aftermath; rowen.

lattermath, *n.* Aftermath.

rowen, *n.* Aftermath.

haymaking, *n.* The process of converting herbage into hay.

mow (mō), *v. t.* 1. To cut down herbage with a scythe or mowing machine. 2. To cut the herbage from an area, as to mow a field.

mower, *n.* 1. One that mows. 2. A mowing machine.

cut, *v. t.* To sever for gathering.

swath, *n.* A strip of cut herbage as left by a scythe or mower.

rake, *v. t.* To collect with a rake.

windrow, *n.* Partially cured math raked into a row.

windrow, *v. t.* To rake into windrows.

ted, *v. t.* To spread out or to scatter slightly mown herbage to facilitate curing or drying.

cock, *n.* A small conical or rounded pile of hay, especially while curing.

haycock, *n.* A cock of hay.

cock, *v. t.* To put hay into cocks.

cure, *v. t.* To prepare for preservation, as of cut plants into hay, by drying.

sweat, *n.* The emission of moisture, usually accompanied by heating, as of green cut plants in a heap.

sweat, *v. i.* To emit moisture, usually accompanied by heating.

stack, *n.* A large pile of hay, unthrashed grain, or straw in the open.

haystack, *n.* A stack of hay.

stack, *v. t.* To build or put into a stack.

rick, *n.* A stack of hay or grain, rectangular at the base.

hayrick, *n.* A rick of hay.

rick, *v. t.* To place in a rick; to build a rick.

hayloft, *n.* An elevated floor or scaffold in a barn for storing hay.

mow, (mou), *n.* 1. A mass of hay in a barn. 2. The place where hay is stored in a barn.

haymow, *n.* 1. A mass of hay in a building. 2. The place where hay is stored in a barn.

mow, *v. t.* To place or store hay in a mow.

stubble, *n.* The basal portion of the stems of plants left standing in the field after cutting the crop.

silage, *n.* Forage preserved in a succulent condition by partial fermentation in a tight receptacle; ensilage.

silo, *n.* A tight receptacle designed to contain vegetable matter so that it will ferment under nearly anaerobic conditions.

ensile, *v. t.* To put vegetable matter into a silo to make silage.

ensilage, *n.* Silage.

palatability, *n.* The quality or combination of qualities which makes feed agreeable to animals as evidenced by their eating it readily.

succulent, *adj.* Full of juice; juicy.

NITRIFICATION AND TOTAL NITROGEN AS AFFECTED BY CROPS, FERTILIZERS, AND COPPER SULFATE.[1]

Chas. A. Jensen,

Bureau of Plant Industry, U. S. Department of Agriculture.

Introduction.

This paper deals with a study of the changes in nitrification and total nitrogen under field conditions at Rocky Ford, Colo., during the summers of 1911 and 1912. The object of the nitrate determinations made in 1911 was to find some cheap and practical method of counteracting the detrimental effects of excessive nitrate accumulations which, during the seasons of 1910 and 1911, gave promise of becoming a serious factor in beet culture on certain soils in the Arkansas River Valley in Colorado.

Excessive amounts of nitrates in the soil tend to produce a large, coarse, and brittle beet which does not ripen properly in the fall and which is apt to be low in both sugar content and purity. Such beets generally do not work up well in the factory and their low sugar content and low purity reduce the sugar yield and increase the molasses, hence the beets are expensive to work.

It may be stated here that while the accumulations of nitrates were on the increase in 1910 and 1911 in the Arkansas River Valley in Colorado, the accumulations were less marked in 1912 and 1913 and have since ceased to be a serious factor in the area to which these investigations were confined. The distribution of the nitrate areas and the excessive nitrate accumulations in the area here studied, as well as in other portions of the state, have been quite extensively reported upon by Dr. Headden of the Colorado station.[2]

The results which follow are published by permission of Mr. E. C.

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[1] Received for publication July 2, 1915.

[2] Headden, Wm. P., The Fixation of Nitrogen in Some Colorado Soils, Colo. Agr. Expt. Sta. Bul. 155, 1910.

———, Nitrates in the Soil, Colo. Agr. Expt. Sta. Bul. 160, 1910.

———, The Fixation of Nitrogen in Some Colorado Soils, Colo. Agr. Expt. Sta. Bul. 178, 1911.

———, Deterioration in the Quality of Sugar Beets Due to Nitrates Formed in the Soil, Colo. Agr. Expt. Sta. Bul. 183, 1912.

Howe, general manager of the American Beet Sugar Company, whose interest in investigational work made it possible to secure much information relating to plant nutrition. The writer also especially wishes to acknowledge his many obligations to Mr. H. E. Zitkowski, chief chemist for the company at Rocky Ford, for his hearty support and intelligent cooperation in all the work here reported. Most of the chemical determinations were made during the intercampaign periods by the regular chemists of the company.

EXPERIMENTS IN 1911.

A 10-acre field of clay loam soil seeded to winter wheat in the fall of 1910 showed considerable winterkilling in the spring of 1911 and preliminary determinations showed unusual amounts of nitrates where the wheat was most injured. The stand of wheat was so poor that the crop was not considered worth caring for, and this field was selected for experiments in testing the effects of various treatments on nitrification in the field. The field lies rather low but is not seepy, though ground water was within 4 or 5 feet of the surface and drainage of the field was under consideration. There were no alkali accumulations in the soil, in the usual meaning of the term.

The winter wheat was disked up and the field was divided crosswise into three sections in such a manner that Section 1 at the lower end of the field included the wheat most affected by winterkilling and contained the most nitrates. Section 3 was the best section so far as the stand of wheat was concerned and it also contained the least nitrates. The field was next divided lengthwise into nine plots of about 1 acre each, each plot traversing the three sections into which the field was divided crosswise. Four of the nine plots were seeded to mustard, sorghum, sweet clover, and oats respectively, the seeding being done May 15. No stand was obtained on the plot seeded to sweet clover, so the weeds which came up in abundance were allowed to grow. The remaining five plots were fallowed. One was reserved as a check while the other four received applications respectively of copper sulfate, manure, factory waste lime, and factory waste molasses. The copper sulfate and molasses were each applied twice, on May 2 and May 20. Fifty pounds of copper sulfate and a quantity of molasses equivalent to 50 pounds of dry matter were used for each application. These two substances were dissolved in water and applied in a fine spray by means of a power spraying machine.

The waste lime used in the experiment was the material filtered out of the sugar-beet juices after these are treated with lime hydrate and with carbon dioxid. The molasses was the waste product from the centrifugals which, after passing through the factory processes a number of times, finally becomes so charged with impurities that further extraction is unprofitable. The analyses of the lime and manure used are given in Table 1 and that of the molasses in Table 2. The figures for the lime and manure are given in percentages of dry matter, so far as the constituents were determined. The CO_2 was not determined in the lime, which would practically make up the remainder of the material not accounted for in the analysis.

TABLE 1.—*Analyses of manure and waste lime applied to the land in experiments near Rocky Ford, Colo.*

Constituent.	Manure.	Waste lime.
	Percent.	*Percent.*
Organic matter	37.96	8.00
Insolubles in HCl	43.63	17.95
SiO_2 (soluble)	.14	.38
Fe_2O_3	3.29	.88
Al_2O_3	4.16	2.25
CaO	3.88	38.57
MgO	.26	1.22
K_2O	2.54	.54
Na_2O	.67	.12
SO_3	1.18	.99
P_2O_5	.75	.68
N	1.52	.23

TABLE 2.—*Analysis of factory waste molasses applied to the land in experiments near Rocky Ford, Colo.*

	Percent.
Dry substance	83.41
Real purity	64.98
Raffinose	2.74
Total nitrogen in dry substance	2.07
$NaNO_3$ in dry substance	3.16
Carbonated ash	11.63

The manure and the lime were each applied at the rate of 15 tons per acre and were thoroughly disked and harrowed in. All the plots were uniformly irrigated when the soil became dry enough to need irrigation, and all fallow plots were disked and harrowed to maintain a mulch.

Soil samples were collected every week from each plot in each section, four borings being made for each individual composite sample at each time. The depths of sampling were from 0 to 2 inches and from 2 to 12 inches. The samples were immediately prepared for analysis. The nitrates were determined by the phenoldisulfonic acid method, as given in Bulletin No. 31 of the U. S. Bureau of Soils. The determinations of nitrate nitrogen in the 2 to 12 inch depth were abandoned during the summer, as the amounts found were so uniformly small that for the purposes of the work the determinations were of no practical consequence.

DETERMINATION OF NITRATE NITROGEN.

Table 3 shows the weekly determinations of nitrogen as nitrates to a depth of 2 inches in Section 1, expressed as pounds per acre in the dry soil. Table 3 also shows the results of similar determinations in Section 2 and 3, the figures given being the average of the amounts found in both sections. In Table 3 the treatments are arranged from left to right in the order of the average amounts of nitrate nitrogen found throughout the season. This section, it will be noticed, contained more nitrates than Sections 2 and 3. Nitrification in these sections was not as strong as in Section 1 and the average amounts found did not vary much among the cropped plots with the exception of that on which mustard was grown. This latter contained the least amount of nitrates in most cases.

Cold weather and rains between the first and second sampling and an irrigation followed by a heavy rain on July 5 and 6 evidently diminished the nitrates, as shown by the sampling on April 28 and July 12 respectively. Aside from these supposedly effective factors, the large weekly variations can not be accounted for by the data available.

The mustard did not do well, reaching a height of only 10 to 12 inches, and during the latter part of the summer it was badly damaged by a flea beetle. The stand was thin, and the yield was estimated at only about 2,500 pounds of green material. The average amount of nitrate in the fallow plot exceeded that in the mustard plot by 27 pounds per acre 2 inches of soil in Section 1 (Table 3). If we assume that all this nitrate nitrogen was taken up by the mustard plants, it would produce a plant containing about 35 percent nitrogen calculated on the dry weight. It is possible, however, that this plant had the power of altering the soil flora in such a manner as to check nitrification. The other three crops made a good growth, much more rank than the mustard, and, as will be seen from Table 3, the nitrate content of the soil was much higher than in the mustard plot.

TABLE 3.—*Pounds per acre of nitrate nitrogen in surface 2 inches of soil in Section 1 and the average number of pounds per acre in Sections 2 and 3.*

SECTION I.

Date.	Mustard.	Fallow + CuSO₄.	Oats.	Sorghum.	Fallow + molasses.	Weeds.	Fallow.	Fallow + manure.	Fallow + lime.	Average.
Apr. 19	26	24	3	16	14	22	28	41	26	22
Apr. 28[a]	1	2	5	1	4	4	5	1	6	3
May 4	30	10	32	5	17	21	17	17	21	19
May 11	1	2	2	7	2	1	6	7	6	4
May 17	8	7	22	16	30	10	91	17	24	24
May 24	17	28	28	42	—	18	32	32	44	30
May 31	10	26	22	18	8	12	32	56	64	28
June 7	7	36	37	45	—	25	42	72	76	43
June 14[b]	7	48	10	47	31	5	51	38	35	30
June 21	5	19	36	7	39	47	63	21	108	38
June 27	75	26	13	72	60	177	69	115	139	83
July 5[b]	17	31	97	55	100	50	58	34	43	54
July 12	3	29	13	33	22	83	12	79	21	33
July 19	14	7	2	2	13	21	11	22	7	11
July 26	5	18	9	11	7	8	7	5	1	8
Aug. 2	1	11	1	1	11	1	11	13	4	6
Aug. 9	5	2	6	4	13	8	2	5	2	4
Aug. 17	1	3	6	2	3	5	7	5	7	4
Average	13	18	19	21	27	29	30	33	42	
AVERAGE OF SECTIONS 2 AND 3.										
Apr. 19	3	5	13	3	8	4	4	15	4	7
Apr. 28[a]	3	1	2	4	2	1	1	7	5	3
May 4	4	10	4	3	5	2	6	13	9	6
May 11	—	—	—	—	—	—	—	—	—	—
May 17	13	9	14	9	4	5	13	17	73	18
May 24	14	13	14	11	12	9	12	31	26	16
May 31	5	12	6	8	6	8	14	26	12	11
June 7	4	18	6	7	—	7	20	51	69	23
June 14[b]	—	—	—	—	—	—	—	—	—	—
June 21	14	38	26	23	16	27	47	58	106	39
June 27	11	17	41	11	37	11	52	62	123	41
July 5[b]	22	11	21	26	43	17	20	30	11	22
July 12	25	51	45	28	13	53	77	125	92	57
July 19	3	8	7	4	7	1	5	7	29	8
July 26	5	5	7	4	3	9	3	3	5	5
Aug. 2	1	4	1	1	5	2	4	6	3	3
Aug. 9	4	4	6	3	3	3	7	6	4	4
Aug. 17	5	3	9	5	2	2	7	5	9	5
Average	9	13	14	9	11	10	19	29	34	

[a] Rains about this date.

[b] Irrigated.

Copper sulfate was also quite effective in checking nitrification, as will be seen by comparing the nitrate content of this plot with that of the untreated fallow plot used as check. Assuming the copper sulfate to have been uniformly distributed through the surface 6 inches of soil, the concentration would be about 50 parts per million. Excepting the amounts of nitrates found on June 14 in this plot this concentration appears to have been sufficient to check the nitrification considerably. It will be noticed that this plot contained as much nitrate as the others until the copper sulfate was applied, after which the nitrate content decreased. Lipman and Burgess[3] found a stimulation with this salt, but the conditions of the two experiments were so different that no comparison can properly be made.

The waste molasses compared with the fallow alone also had an apparently depressing influence on nitrification. In most cases the waste lime and manure increased nitrification, but the lime caused an earlier and more intense stimulation than the manure.

In general, nitrification did not increase greatly until about the first part of June, and from then until the middle of July. The concentration of nitrates suddenly decreased about the middle of July, and remained low until the end of the experiment, August 17. The same general increase in the activity of the nitrifying organisms during early summer, followed by a decided decrease in the latter part of the summer, was also observed by the writer at the Belle Fourche Experiment Farm,[4] and seems to be a natural phenomenon of field nitrification regardless of soil treatment. The data on the average weekly fluctuations in all the plots, given in the right-hand column in Table 3, show the seasonal increase and decrease plainly. Russell,[5] in an extended investigation of the subject, observed the same general phenomenon, and says: "In almost all the soil examined the accumulation of nitrate took place most rapidly in late spring or early summer. After this there was usually little, if any, gain and very frequently a loss." "During the winter, loss of nitrate took place."

DETERMINATIONS OF TOTAL NITROGEN.

Three sets of total nitrogen determinations were made during the season, the results of which are shown in Table 4. These were made on samples taken from 0 to 2 inches and from 2 to 12 inches in depth.

[3] Lipman, C. B., and Burgess, P. S., The Effect of Copper, Zinc, Iron, and Lead Salts on Ammonification and Nitrification in Soils, Univ. of Cal. Pubs. in Agr. Science, vol. 1, no. 6, March, 1914.

[4] Jensen, C. A., Seasonal Nitrification as Influenced by Crops and Tillage, U. S. Dept. Agr., Bur. Plant Indus. Bul. No. 173. 1910.

[5] Russell, E. J., The Nature and Amount of Fluctuations in Nitrate Contents of Arable Soils, Jour. Agr. Science (Cambridge), vol. 6, part 1, January, 1914.

TABLE 4.—*Pounds per acre of total nitrogen minus nitrate nitrogen in the surface 2 inches and the 2-12 inch depth in Section 1, as determined on three dates, with the averages for each depth.*

Depth and date.	Mustard.	Sorghum.	Fallow + $CuSO_4$.	Weeds.	Oats.	Fallow + molasses.	Fallow + manure.	Fallow + lime.	Fallow.	Average.
SURFACE 2 INCHES:										
May 17	581	632	578	622	636	636	718	696	732	648
June 21	379	358	560	526	504	466	436	520	548	476
July 12	578	581	510	548	560	628	682	622	738	604
Average	512	522	548	564	568	581	612	612	672	
AT DEPTH OF 2-12 INCHES:										
May 17	1,833	2,490	2,337	2,023	2,383	2,426	2,053	2,187	2,503	2,210
June 21	1,510	2,347	1,947	2,193	1,850	1,977	2,287	2,170	2,240	2,057
July 12	2,849	2,783	2,737	2,673	2,833	2,923	3,284	2,863	2,820	2,860
Average	2,063	2,540	2,340	2,297	2,357	2,330	2,540	2,407	2,213	
AVERAGE FOR FIRST FOOT	2,310	2,820	2,532	2,563	2,597	2,643	2,820	2,732	2,937	

The total nitrogen was in almost all cases less on June 21 than a month earlier or a month later. The nitrification, however, increased considerably from the middle of June until July 5, after which period it rapidly decreased. Whether there was any physiological relation between this increased nitrification with decreased total nitrogen in the middle of June or the decreased nitrification with increased total nitrogen in the middle of July was not investigated more closely. As this reversed relation, however, holds good in almost all the plots regardless of treatment, in both the surface 2 inches and in the depth from 2 to 12 inches, it would hardly seem to be accidental.

The average total nitrogen content of the different plots does not follow the same order as the average seasonal amounts of nitrates, but in both cases the mustard plot stood lowest and in general the fallow plots, with the exception of that to which molasses was added, stood highest. Both copper sulfate and molasses were effective in checking nitrification.

EXPERIMENTS IN 1912.

The work discussed in the preceding paragraphs was done in 1911. In 1912 a similar set of determinations was made on a field of sandy loam soil which had been in alfalfa for a number of years, and which was broken up and planted to beets in 1912. The alfalfa was crowned in the fall of 1911, and the field plowed in the spring of 1912 to a depth of about 8 inches. The roots were removed as thoroughly as possible, both in the fall when the alfalfa was crowned and in the spring when it was plowed. The whole field had been used to some extent for a horse pasture but there was no noticeable manurial effect from this use.

After the preparation of the ground for beets, the field was laid out in plots in duplicate, and the following amounts of fertilizer applied per acre to the various plots: Nothing; sodium nitrate, 300 pounds at seeding time and 300 pounds when the beets were thinned; calcium cyanamid, 500 pounds; superphosphate, 500 pounds; bone meal, 500 pounds; factory waste lime, 15 tons; composted manure. 14 tons; ordinary dry yard manure, 14 tons, plus 300 pounds ammonium sulphate. Owing to the conditions and circumstances existing, the manure, lime, and the artificial fertilizers could not be applied until spring, which, according to numerous other observations. is not as good a time to apply manure and waste lime as the fall, at least so far as nitrification and sugar beet growth are concerned. The beets were planted during the first part of May and the plots were all irrigated uniformly whenever necessary, which was about every 10 to 12 days.

DETERMINATIONS OF NITRATE NITROGEN.

In considering the amounts of nitrates found in the various plots, as shown in Table 5, it should be borne in mind that the sugar beet is a fairly strong feeder and that it makes its most rapid growth during the time that nitrification is most active. It might therefore be inferred that any differences in the accumulation of nitrates in the various plots ought to indicate real differences in nitrifying activity as influenced by the fertilizers, providing the yields were fairly uniform. Soil samples to a depth of 12 inches were taken weekly beginning May 16 for the determination of nitrate nitrogen and total nitrogen. The ratio of soil to distilled water used in making the extracts was 1 to 5. The solutions were thoroughly stirred, allowed to stand usually about 30 minutes, filtered through Pasteur-Chamberlain filters, and analyzed according to the methods described in Bulletin 31 of the U. S. Bureau of Soils.

As was the case the preceding year, the nitrates fell off markedly after the latter part of July, emphasizing again the point that nitrification in the field under natural conditions proceeds much less rapidly during the latter part of the summer. When the work was begun, May 16, nitrification was already well started, and the general averages during the season show that for all the treatments there was no marked accumulation of nitrates during the summer as was the case in 1911, especially in the fallow plots. Table 5 shows the amount of nitrate nitrogen found in the weekly samples in the first foot of soil.

Table 5.—*Pounds per acre of nitrate nitrogen in the surface foot of soil in sugar beet plots variously treated, as determined at several dates in 1912.*

Date.	Nothing.	Nitrate.	Cyanamid.	Phosphate.	Bone meal.	Waste lime.	Composted manure.	Dry manure.	Manure + $(NH_4)_2SO_4$.	Check.	Average.
May 16...	24	120	40	45	36	54	18	54	105	24	54
May 27...	80	84	88	68	52	62	38	36	146	80	73
June 3...	53	28	72	60	50	32	36	31	120	59	54
June 10...	48	42	74	40	36	48	74	38	120	64	58
June 17...	27	19	88	32	16	20	44	17	97	26	38
June 24...	140	124	172	128	38	60	80	44	260	128	94
July 1...	12	10	56	28	30	30	34	18	52	20	29
July 8...	31	150	84	34	24	10	92	48	72	105	65
July 15...	68	44	116	44	20	32	48	28	80	76	55
July 22...	140	20	108	40	28	12	52	56	108	92	65
July 29...	12	12	12	16	12	12	60	20	104	36	29
Aug. 5...	8	16	16	8	12	8	16	12	12	16	12
Aug. 12...	8	12	32	12	8	12	12	16	36	8	15
Aug. 19...	12	8	8	8	8	12	20	44	8	8	13
Aug. 26...	4	4	56	8	4	8	16	8	16	4	13
Average...	44	46	68	40	24	27	43	32	89	50	

The beet plot which received manure and ammonium sulfate showed the greatest nitrifying activity, as might be expected. This plot, being separated from the others by about 40 feet, had a check plot of its own, given in next to the last column to the right in Table 5. The only other plot that showed more nitrates than the check was the cyanamid plot. If the increased activity in this plot was due to the formation of ammonia in the decomposition of the cyanamid, which was presumably the case, the ammonia was evidently formed fairly slowly or it was retained in the soil in an easily available condition during the summer.

It is of interest that the ordinary yard manure did not promote as high nitrification as the composted manure, though the difference is not great. It is rather puzzling that the waste lime, which gave such high results the preceding year on fallow, should give such low results here. It can only be suggested, without any supporting evidence, that the beets utilized the nitrates quite fully, because this fertilizer produced large beet growth. Apparently bone meal and superphosphate checked nitrification, and these substances did not produce large beet growth under the conditions. On the whole, it is evident that none of the treatments except the cyanamid and the manure plus ammonium sulfate produced any greater increase in nitrates than was absorbed by the beets.

That the fertilizer treatments were not without effect on nitrification would seem a reasonable conclusion from the comparison of the relative beet yield and the seasonal nitrate averages, as shown in Table 6.

TABLE 6.—*Relative yields of beets from plots variously treated, with the average number of pounds per acre of nitrate nitrogen for each plot, as determined at various dates.*

Treatment.	Check.	Nitrate.	Cyanamid.	Phosphate.	Bone meal.	Waste lime.	Composted manure.	Dry manure.	Manure + $(NH_4)_2SO_4$.
Relative yields...	100	120	119	119	133	135	121	118	176
Average N as NO_3.	44	46	68	40	24	27	43	32	89

It is evident from Table 6 that there is no regular inverse relation between beet yields and nitrate accumulations. While the yields were not by any means uniform, the figures do not show that the increased beet yields were necessarily the cause of low nitrate accumulations.

DETERMINATIONS OF TOTAL NITROGEN.

In Table 7, the total nitrogen determinations are given. Considering the seasonal averages for all the treatments, it is apparent that the total nitrogen content diminished somewhat from the first part of July. There was evidently a tendency for this element to decrease slowly throughout the summer, though there was not much change from June 24 to July 22. The average amounts of total nitrogen for the season show no evident correlation with the amounts of nitrate nitrogen found, although the different fertilizer treatments are not necessarily without effect on the organic nitrogen. The increased nitrogen found for a time in the manure plots can be accounted for by the nitrogen applied in the manures, which amounted roughly to 800 pounds per acre. About 300 pounds per acre were added in the lime, but the other fertilizers did not contain sufficient nitrogen to account directly for the increases over the checks. It would therefore seem that there was an actual loss of total nitrogen on the manured plots, especially on the plot receiving both manure and ammonium sulfate; and that there was a gain on the lime and cyanamid plots and also on those receiving the phosphatic fertilizers.

TABLE 7.—*Pounds per acre of total nitrogen minus nitrate nitrogen in the surface foot of soil in sugar beet plots variously treated, as determined at several dates in 1912.*

Date.	Nothing.	Nitrate.	Cyanamid.	Phosphate.	Bone meal.	Waste lime.	Composted manure.	Dry manure.	Manure + $(NH_4)_2SO_4$.	Check.	Average.
May 27...	3,400	4,340	5,380	4,240	4,220	5,300	3,420	4,960	3,920	3,380	4,256
June 3...	4,080	4,240	5,200	4,740	4,560	5,060	5,080	4,380	4,260	4,440	4,664
June 10...	3,880	4,480	4,560	3,960	4,760	3,920	5,060	4,780	4,700	3,780	4,388
June 17...	3,600	3,580	4,680	3,880	4,360	4,040	3,800	4,440	3,840	3,240	3,936
June 24...	3,600	3,620	4,680	3,580	3,720	4,380	3,920	4,280	4,120	3,880	3,980
July 1...	3,240	3,040	4,240	3,720	4,040	4,160	4,280	4,640	3,480	2,960	3,780
July 9...	3,940	3,840	4,320	3,940	3,820	4,060	3,980	3,920	3,960	4,000	3,980
July 15...	3,640	3,480	4,520	3,820	4,120	3,920	3,760	3,360	3,680	3,480	3,776
July 22...	3,840	3,640	4,080	3,320	3,920	4,360	3,360	3,760	3,720	3,240	3,724
July 29...	3,480	3,240	3,680	3,480	3,240	3,480	3,640	3,280	3,480	3,200	3,420
Aug. 5...	3,120	3,320	4,120	3,680	3,860	3,640	3,960	3,680	3,560	3,080	3,572
Aug. 12...	3,720	3,720	3,800	3,840	3,280	3,560	3,680	3,680	3,280	2,520	3,508
Aug. 19...	3,520	2,840	3,960	2,920	3,400	3,120	3,360	3,760	3,360	2,640	3,328
Aug. 26...	2,680	3,760	3,760	3,400	3,360	4,240	3,920	3,960	3,360	2,560	3,500
Average..	3,596	3,652	4,356	3,752	3,884	4,088	3,936	4,064	3,768	3,312	

It is of interest that the total nitrogen decreased throughout the season in all the plots regardless of fertilizer treatment, the average decrease being about 900 pounds per acre, as shown in Table 7. Table 8 also shows a similar though small loss in the second foot of soil. The greatest losses of nitrogen occurred from the plots receiving cyanamid, phosphate, bone meal, and manure plus sulfate. With one exception the cyanamid plot accumulated the most nitrate and also lost the most total nitrogen. On the other hand, the plots receiving phosphate and bone meal lost heavily in total nitrogen but produced the smallest accumulations of nitrate. What was true of the cyanamid plot also held true for the plot receiving manure and sulfate. The decrease in total nitrogen does not seem to be due entirely to nitrification, and certainly not all of the nitrogen that was lost could have been absorbed by the crop. The average loss was about 900 pounds of nitrogen per acre-foot, while the best yields actually obtained did not remove 100 pounds per acre in both leaves and roots. There was therefore a loss of about 800 pounds of nitrogen per acre. The loss in nitrogen was not proportional to the yields from the plots.

Nitrate Nitrogen and Total Nitrogen in the Second Foot of Soil.

Table 8 shows the nitrate nitrogen and total nitrogen in the second foot of soil, but these determinations were not begun until July 15. There was very little nitrification at that depth, though there was a fair nitrifying activity in the first foot when these determinations were begun. The total nitrogen content in the second foot was roughly about 60 percent of that in the surface foot, but the relative order of the plots is not the same as for the first foot of soil. In fact, the amounts of organic nitrogen in the second foot would suggest that fertilizer applications in the surface foot did not very appreciably affect the accumulation of the organic nitrogen in the second foot during the year the fertilizer was applied.

TABLE 8.—*Pounds per acre of nitrate nitrogen and total nitrogen in the second foot of soil in sugar beet plots variously treated, as determined at several dates in 1912.*

POUNDS PER ACRE OF NITRATE NITROGEN.

Date.	Nothing.	Nitrate.	Cyanamid.	Phosphate.	Bone meal.	Waste lime.	Composited manure.	Dry manure.	Manure + $(NH_4)_2SO_4$.	Check.	Average.
July 15...	16	24	24	28	12	12	28	20	48	48	
July 22...	20	52	72	24	8	8	20	12	12	20	
July 29...	24	12	12	12	12	8	20	8	52	20	
Aug. 5...	8	8	8	8	4	8	4	12	4	8	
Aug. 12...	8	12	8	8	12	8	12	16	28	8	
Aug. 19...	4	4	4	4	4	4	4	40	4	4	
Aug. 26...	4	4	4	4	4	4	4	8	12	4	
Average...	12	16	12	3	8	8	12	16	24	16	

POUNDS PER ACRE OF TOTAL NITROGEN.

July 15...	2,520	2,280	2,400	2,560	2,280	2,280	2,520	2,520	2,080	2,280	2,372
July 22...	2,480	2,120	2,280	2,000	2,080	2,560	2,350	2,520	2,200	2,000	2,252
July 29...	2,360	2,080	2,000	2,000	2,360	2,400	2,200	2,480	2,000	2,480	2,236
Aug. 5...	2,760	2,240	2,400	2,920	2,280	2,280	2,420	2,280	1,920	1,840	2,204
Aug. 12...	2,360	1,840	2,520	2,240	1,960	2,280	1,960	2,440	2,040	1,600	2,124
Aug. 19...	2,360	1,800	2,280	1,840	2,000	1,880	1,840	2,720	1,800	1,680	2,020
Aug. 26...	2,280	2,000	2,400	2,080	2,680	2,960	2,360	2,240	1,840	1,920	2,176
Average...	2,440	2,040	2,320	2,080	2,240	2,240	2,200	2,480	1,960	1,960	

SUMMARY.

The accumulation of nitrates in the soils in the Arkansas River Valley in Colorado, which promised in 1910 and 1911 to become a serious factor in sugar beet growth, became less in 1912 and 1913.

In the work in 1911, mustard appeared to have some effect in checking the accumulation of nitrate in the field. Copper sulfate at the rate of 100 pounds per acre on fallow was also effective in checking nitrification, reducing the average seasonal accumulation to about 60 percent of the amount found in the check plot. Molasses on fallow decreased nitrification about 25 percent as compared with the check, but the molasses-treated plot showed a little more nitrates than the plots cropped to cane and oats. Manure on fallow gave a slightly higher accumulation of nitrates than the fallow check. The waste lime on fallow caused strong nitrate accumulation, being more effective in this regard than any other treatment.

In general, active nitrification did not set in until the first part of June. From then until the middle of July it was strongest, and then suddenly decreased and became very feeble until the end of the experiment, August 17, regardless of the field treatments. The differences in the average seasonal accumulations of nitrates could not have been due entirely to the differences in beet yields from the plots.

The mustard plot contained less total nitrogen than any of the others. The fallow plots receiving copper sulfate and molasses contained less total nitrogen than the other fallow plots. The fallow plots with waste lime and manure each contained less total nitrogen than the plot fallowed with nothing added. The reverse was true as regards nitrates.

In general, there seemed to be an inverse relation between the amounts of nitrates and amounts of total nitrogen.

In the work in 1912, in the presence of a vigorously growing beet crop, the only treatments which showed decided increases in nitrification were cyanamid and manure plus ammonium sulfate.

Aside from considerable weekly variations, there was not much change in nitrification from the middle of May till the latter part of July, after which the nitrifying activity was very low and remained so until the end of the experiment, August 26.

Bonemeal, superphosphate, waste lime, and dry yard manure decreased the nitrifying activity. Composted manure produced a slightly higher nitrifying activity than did the dry yard manure, but both these plots showed slightly less nitrates than the checks.

The total organic nitrogen in the first foot showed a general decrease from the latter part of May to the latter part of August, amounting on the average to about 900 pounds per acre. This decrease was least from the middle of June to the middle of July. There was also a slight loss of organic nitrogen from the second foot during the same period.

It is shown that the seasonal loss of organic nitrogen could not be accounted for by the amounts removed in the crop.

No correlation could be established between the nitrate content and the total nitrogen.

Taking into account the nitrogen applied in the manures and lime, the manured plots lost most nitrogen, especially those to which ammonium sulfate was added, while the limed plots showed a gain in total nitrogen. The plots receiving cyanamid, phosphatic fertilizers, and nitrate showed a slight gain in total nitrogen over the checks. The total nitrogen content in the second foot was unaffected by the fertilizers applied in the first foot. The nitrifying activity in the second foot was very low.

SOIL ACIDITY AND THE LITMUS PAPER METHOD FOR ITS DETECTION.[1]

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Introduction.

The matter of soil acidity is one of the live topics of the day among soil chemists and other soil investigators. There has been a vast amount of investigation of the subject and it has come to be quite generally recognized in recent years that cultivated soils tend to become acid.

Historical.

Probably the most popular and widespread theory of soil acidity is that the acids of the soil are largely organic. The most common of these are the so-called humic, ulmic, crenic, and apocrenic acids, which were isolated and named by the early investigators, Sprengel, Brezelius, and Mulder. They assigned definite chemical formulas to these compounds, and their work formed the basis of our present knowledge of soil organic acids. More recently it has been shown that these acids are not definite chemical compounds, but are mixtures of several simpler organic acids. Recent work by the United States Bureau of Soils has added several new soil organic acids with definite chemical composition, which constitute what was previously known as humic acid.

It has been repeatedly observed that soils containing large amounts of organic matter often gave an acid reaction. This acidity was generally attributed to complex organic acids which arose from the decompositon of vegetable matter in the soil. It was supposed that these organic acids required lime for neutralization and if lime was deficient the acids accumulated. However, it was not believed that all soils rich in humus are acid.

Some men think that these soil organic acids exist as free insoluble acids, while others think that they exist in the soil united with the soil bases. Nevertheless, when a water extract is taken from acid soils, it is nearly always neutral or alkaline, which would tend to show that,

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[1] Contribution from the Department of Soils, University of Missouri. Received for publication August 2, 1915.

whatever their nature, these soil acids are not soluble in water. Consequently, the methods of Hopkins, Pettit, Knox, and many others, for the determination of soil acidity are based on the theory that when a neutral salt solution is added to an acid soil a double decomposition takes place whereby a soluble acid is set free.

$$R-COOH+KNO_3=R-COOK+HNO_3.$$

In this connection mention might be made of the use of green manures. It is often said that turning under excessive amounts of green manure tends to make soils acid. This fact, however, has never been proved and no experimental evidence has been found to uphold the belief.

Loew[2] has another explanation of soil acidity. He makes a distinction between soil acidity due to humic acid and that due to mineral compounds. Loew attributes the acidity of some of the clay soils of Porto Rico to an acid clay to which he assigns a definite formula and calls argillic acid. The formation of this acid clay seems to be especially favored by heavy rains and a high summer temperature whereby the carbonate of lime formed by disintegration of rock particles is gradually dissolved and leached out, and finally even the lime combined with the clay is removed. In neutral clays the acids formed would be neutralized by bases such as potash, soda, and lime.

Another cause of soil acidity has been connected with the use of certain fertilizers. Some investigators say that the long continued use of ammonium sulfate tends to make the soil acid. The nitrogen is assimilated by the plants, thus leaving sulfuric acid in the soil. The addition of ammonium sulfate to an acid soil may actually be a detriment because it increases the acidity and thus further hinders the work of nitrification.

Acid phosphate, though not normally acid in itself, when added to the soil often tends to make the soil acid. The Ohio station has proved the above statements by the growth of clover on unlimed plots treated with ammonium sulfate and acid phosphate. On the unlimed soil where nitrate of soda furnished the nitrogen and the phosphorus was supplied in bonemeal, some clover grows, while on unlimed soil where acid phosphate and ammonium sulfate are used alone the clover is a complete failure.

Harris[3] has made some objections to the theory of Hopkins, Pettit,

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[2] Loew, Oscar, Studies on Acid Soils of Porto Rico, Porto Rico Agr. Expt. Sta. Bul. No. 13. 1913.

[3] Harris, J. E., Soil Acidity, Mich. Agr. Coll. Expt. Sta. Tech. Bul. 19, 1914.

Knox, and others that a double decomposition takes place when a neutral salt solution is added to an acid soil, thus setting free a soluble acid. He says:

> If the hypothesis upon which this theory is based furnishes the correct explanation for the action of the soil, then the total amount of acid liberated would be the same no matter what salt solution was used. On the other hand, if the action is due to selective adsorption on the part of the soil, we would expect the amount of adsorption to depend more or less on the salt used since some colloidal substances adsorb more of some bases than others.

A table is printed which shows that the greatest amount of acid is set free in the sodium acetate solution, the potassium nitrate coming next and the sodium chloride last. Harris then believes that soil acidity is due to selective adsorption of the soil bases.

The Ohio station strikes a happy medium on this question. Ames and Gaither[4] say that the nature of the acidity or the cause is not the same for all soils. Organic matter in some cases where the drainage is not adequate is an important factor in the production of acidity. In peat soils or in soils where the organic matter is excessive the presence of organic acids is apparent from the solvent action of the water which drains from the peat. In soils which contain scanty supplies of organic matter the acid condition may be due to silicic acid or acid salts of inorganic origin. Cultivated soils develop an increasing acid condition which is indicated by the gradual failure of clover on soils which at one time produced fair yields of cereals. This is particularly noticeable on noncalcareous soils where various fertilizing materials including acid phosphate and ammonium sulfate have been used. The selective absorption capacity of plants where different forms of the essential nutrients are supplied no doubt contributes to an increasing or decreasing degree of acidity.

Most of the investigations of acid soils of late years have been directed toward developing methods for determining quantitatively the degree of acidity or, as it is more commonly called, the lime requirement. Many methods have been worked out, but all are more or less unsatisfactory.

The qualitative methods are fewer in number but are equally as unsatisfactory. The only qualitative method standing on a very firm basis at the present time is the blue litmus paper test. The peculiar thing about this reaction is that the test paper must be brought into contact with the soil particles for the change in color to take place readily. When the clear water solution of an acid soil is tested with

[4] Ames, J. W., and Gaither, E. W., Soil Investigations, Ohio Agr. Expt. Sta. Bul. No. 261, 1913.

litmus paper it is usually found to be neutral. This has been explained by Cameron of the Bureau of Soils by the fact that certain substances have a selective adsorbing power. For example, metallic silver can be separated from a solution of silver nitrate by the selective adsorbing power of charcoal. Blue litmus will turn red if left in contact for a short time with moist acid-free cotton. This phenomenon can be explained by ascribing to the cotton a selective adsorbing power for the base of the blue litmus salt, the base being adsorbed while the red acid dye remains on the paper. The action of acid soil toward litmus might possibly be explained in this way.

Practically every man has a method of his own in making the litmus paper test for acidity. This would naturally lead to many variations in the test and many conflicting opinions as to its interpretations. Here is what some of the authorities say for and against the litmus test:

> There is still a more definite test for soil acidity which may be made on the farm—the litmus paper test. (P. E. Brown, Iowa, in speaking of other tests.)
>
> In case of soils slightly acid the litmus test often fails to give a distinct reaction and thus causes confusion. . . . The reddening of litmus paper by carbonic acid is permanent even on drying and hence the precaution of drying the paper after making the test is of no avail in overcoming the objection to the test. The paper also needs to be carefully handled, as the perspiration on a person's fingers often reddens the paper. It does not show the degree of acidity. Rapidity and intensity of reddening of paper depends on sensitiveness of the paper, amount of moisture in the soil and the perfectness of contact of soil with paper. (E. Truog, Wisconsin.)
>
> A very simple and reliable method to detect soil acidity is by the use of blue litmus paper which can be secured of any good druggist. (A. R. Whitson, Wisconsin.)
>
> If the litmus paper turns red rapidly, it will generally indicate the need for lime. (H. J. Patterson, Maryland.)
>
> The reaction with litmus paper is not always very decisive. (Oscar Loew, Porto Rico.)
>
> A very simple and inexpensive test can be made with litmus paper by anyone to determine whether a soil is sour. (J. F. Duggar, Alabama.)
>
> The test when *carefully* performed has an advantage of being simple, rapid, and in general useful even though its results taken alone can not always be relied upon to tell when calcium is deficient in amount. (L. L. Van Slyke, New York.)
>
> The litmus paper method of testing soils is fairly reliable. (A. E. Grantham, Delaware.)
>
> The litmus paper test for soil acidity has been recommended, but we do not regard it as entirely satisfactory. (J. B. Abbott, Indiana.)
>
> It is the best simple test that can be recommended at the present time. (C. A. Mooers, Tennessee.)
>
> The results afforded by its use are not absolutely conclusive, for the reason

that carbonic acid which is a normal soil constituent faintly affects this test, hence it is not proof positive of soil acidity. (J. L. Hills et al., Vermont.)

Method very uncertain but possesses value in the hands of a skilled operator. (H. J. Wheeler, Rhode Island.)

As to the litmus test for soil acidity, little can be said in its favor and much against it. Let us leave the litmus paper in the laboratory where it belongs. (J. A. Bonsteel, U. S. Bureau of Soils.)

EXPERIMENTAL.

The work presented in this paper was an attempt to settle if possible some of the questions regarding the blue litmus paper test, and also to try to find out whether there is any relation between the amount of acidity in a soil as determined by the Veitch method and the length of time it takes to turn the litmus paper a certain standard color. There was considerable difficulty in choosing a standard color so as to be applicable to all soils varying from high to low in lime requirement. The difficulty arises from the fact that soils of a high lime requirement turn the paper a distinct pink in a relatively short time while those of low lime requirement only turn the paper a purplish pink unless allowed to stand for a considerable length of time. After testing the various soils and much experimenting with water colors a color was finally decided upon which was thought to strike a medium. The color decided upon was a distinct pink with a slight purplish tinge.

After the standard color was decided upon the next step was to find if possible the time that it took the various soils of known lime requirement to turn the litmus paper exactly the same shade of color as represented by the standard. After much experimenting with the various soils in comparing colors with the standard, in taking the time accurately and in the general manipulation of the method the final work was commenced. In similar work at the Missouri station it was found that there was considerable variation in the reactions of various kinds of litmus paper manufactured by the different supply houses, so it was deemed necessary in this work to use a good grade of uniform litmus paper. Tests presented in this paper were made by using the glass plate method as used in the laboratories of the Missouri station. This method was evolved after years of experimenting to find a satisfactory method for manipulating the litmus paper test.

The proper way to carry out this test is to place approximately 25 grams of the soil to be tested in a clean dish and add distilled water, mixing to a very thick paste with a spatula. Just enough water should be added so that when placed on a glass plate and compacted against the hand, the mud will gradually settle down against the glass. After the proper amount of water has been added lay two strips of blue litmus on a clean glass plate about 4 or 5 inches square. The mud is then placed on top of the litmus paper and forced against the glass plate by compacting it on the palm of the hand, or a similar glass plate is placed on top of the soil and pressed down firmly so that the litmus paper will be in close contact. When working with a number of samples care must be taken to compact all of them approximately the same. By performing the test in this way the under side of the litmus paper is not discolored with the mud so that by turning the plate over the time it takes the paper to turn pink as well as the intensity of the color can be noticed. The reaction is probably not so quick with this method as with the mudball method used so commonly, owing to the fact that only one side of the paper is in contact with the soil, but the advantages more than overcome this objection. The test as described is of advantage to men who have worked considerably with the litmus paper method in that the time for the reaction to take place and the intensity of color produced can be noticed continually and correlated with that of standard soils of known lime requirements.

Ten samples of each soil were taken and the time required to turn the test paper the same color as the standard was recorded as near as possible. The different soils represented different soil types found in Missouri and several of them were found to have the same lime requirement by the Veitch method. The lime requirement varied from 0 to 5,082 pounds in the soils used. There was very little trouble found in taking the time and comparing the colors with those of high acidity, but it was almost impossible to make a comparison of colors or read the time shown by those of lower lime requirement. This was due to the color change taking place so slowly that no definite change could be recorded. The bluish pink or purple color also always hindered the reading of the test. In some of these soils showing the same acidity this purple color would be replaced by the more distinct pink sooner than in others and no relation could be worked out. However, for those of high acidity there seemed to be some correlation between the time required for the color change to take place and the degree of acidity. In Table 1 the time required to complete the change of color in each test is recorded, as near as it was possible to determine, together with the lime requirement of each soil as determined by the Veitch method.

TABLE 1.—*Time required to complete the change of color of litmus paper in each of 10 tests for acidity with several soils, with the lime requirement for each soil as determined by the Veitch method.*

Soil.	Lime requirement.[a]	Minutes to turn standard color in each test.									
		1	2	3	4	5	6	7	8	9	10
	Lbs.	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*
Lebanon silt loam	4,148	10	10–15	10–15	10	10–15	10	10	10	10–15	10–15
Crawford stony loam..........	5,082	5–10	5–10	5	5	5	5–10	5	5–10	5–10	5
Crawford silt loam	2,310	45	90	50	120	75	80	100	120	45	60
Putnam silt loam	2,772	35–50	50	60	45	90	90	50	45	50	75
Marshall silt loam	2,772	45	75	80	90	120	50	40	80	90	50
Oswego silt loam .	4,156	10	10–15	15–20	10–15	15	10	10	10–15	10–15	10–15
Shelby silt loam .	3,696	20–25	20	20	20	15–20	15	15–20	15–20	20–25	20
Upland silt, stock soil...........	2,772	75	60	40–45	120	120	90	50	75	80	45
Second 4 in. from Plot 18, Rotation field......	2,772	120	120	50	75	90	45	80	50	40–45	60
First 4 in. from Plot 19, Rotation field......	5,082	10	10	5–10	5–10	5–10	15	10	15	10	5–10
First 5 in. from Plot 17, Rotation field......	5,082	10	10	10	5–10	5–10	10	15	15	5–10	5–10
First 4 in. from Plot 18, Rotation field......	1,386		Indefinite.								
Knox silt loam . . .	Neutral		Very light pink at end of two hours.								
Clay loam, stock soil...........	462		Slight pink in two hours.								

[a] Determined by the Veitch method and figured on the basis of 2,500,000 pounds of soil. Expressed in pounds of $CaCO_3$.

CONCLUSIONS.

It is obvious from the results shown in Table 1 that no definite correlation exists between the time required for the color change and degree of acidity except possibly in the case of acid soils when the lime requirement is 2 tons or more. Even here the correlation is of little value except where the test is made by one man, because no two men would perform it in exactly the same manner. The quantities of water added should be approximately the same and the other details of the test should be carried out practically the same, which is next to impossible. The greatest difficulty, however, would be in comparing the colors and determining the end point. The colors would not look the same to any two persons, hence the inaccuracy of trying to make any correlation to be used by other people. There is a distinct advantage to the person working with soils of known acidity in attempting to make the correlations because it enables him to be able to approximate the lime requirement probably within one ton of $CaCO_3$ per acre fairly accurately. It is surely useless, however, for one man to try to make these correlations for another where there are so many variations and limiting factors.

In view of these and other investigations the litmus paper test for soil acidity should have a prominent place among our qualitative tests. Its special place is in the laboratory where it can be handled by experienced men rather than in the hands of inexperienced farmers. Even to the farmer it has a distinct value, but he should not lay too much stress upon the results obtained.

No correlations can be made between length of time of reaction and degree of acidity except possibly with our more acid soils and even then we must follow a hard and fast method of procedure which eliminates all variations and chances for error.

ACKNOWLEDGMENT.

Acknowledgment is made to Professor M. F. Miller and Mr. C. A. LeClair, under whose direction this experiment was conducted and to whom the writer is indebted for many valuable suggestions received during the progress of the work.

THE NUMBER OF TEMPORARY ROOTS IN THE CEREALS.[1]

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Cornell University, Ithaca, N. Y.

The statement that seeds of the cereals, particularly of corn, upon germination produce either three or four temporary roots has been generally accepted without investigation insofar as the writer has been able to find. Livingston,[2] speaking of corn, says:

> When a kernel is placed in the ground, with conditions favorable for growth, a root shoot called the hypocotyl rapidly pushes downward into the soil. Soon two or three branches grow out from the base of the hypocotyl.

Montgomery[3] makes this statement:

> When a kernel of maize germinates there is produced, first, a root from the tip end of the seed. A few hours later the stem will appear at the upper end of the germ chit. At nearly the same time two roots will be sprouting from about the median joint between root and stem. These are the "temporary" roots and maintain the plant for a short time.

General observations made in class-room tests indicated that there was considerable variation in the number of temporary roots produced by corn and that probably the above statements had been made from an insufficient number of observations. The purpose of this paper is to give some data recently gathered on this subject.

Seeds upon germination first send out what is known as the radicle and a very short time later the plumule appears. The plumule develops into the stem while the radicle is the first and most important temporary root. Next appear whatever other temporary roots that develop, the number varying from none to twelve. Later the permanent roots appear, forming a whorl at the first node, which is usually about an inch below the surface of the soil. The temporary roots during their short period of existence function in the same way as the permanent roots; that is, they absorb water and food material. As the permanent roots develop the temporary roots slowly disappear, as they no longer function in the development of the

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[1] Contribution from the Department of Farm Crops, College of Agriculture, Cornell University. Received for publication July 29, 1915.

[2] Livingston, George, Field Crop Production, p. 31. New York, 1914.

[3] Montgomery, E. G., The Corn Crops, p. 26. New York, 1913.

plant. The so-called radicle, the first root to appear, is considered as the first temporary root and is for this reason included in all the figures given in this paper.

The germinating tests from which the data here presented were obtained were made in a "Standard" germinator which was kept at about optimum temperature for seed germination by means of an electric light. The water was supplied to the seed from the top and the blotters were constantly kept sufficiently moist. When single ears of corn were tested, 100 kernels were taken from each ear. Two rows for the entire length of the ear were shelled and the 100 kernels counted out from this sample. When individual ears of a type or variety were not available, 500 kernels were taken from whatever supply could be obtained, some being shelled samples in the laboratory and some samples of seed from seed firms. The counts on the number of roots were made when the radicles were fully developed and the plumules usually about 2 inches long. It was found by test that after this period no more temporary roots developed. Numerous small fibrous roots will appear, however, on the radicle just below the old kernel and also on the plumule at the first node.

Some of the corn tested was two years old, but the common varieties had been in storage only one year. All the seed obtained in the laboratory had been subjected to occasional high temperatures in an effort to destroy the grain weevil. The heating did not have a very deleterious effect upon the germinating power, as can be seen from Table 1. This table gives the record for the individual ears of four standard varieties of corn, three dents and one flint. The number of temporary roots which were developed by each individual ear, the variations within the individual ears, the mean for each ear, and the total for all the ears in the test are reported.

The germinating percentage was decidedly the lowest in the case of the flint, but there is no correlation between the high germinating percentage and the number of temporary roots. The means as given at the right of the table show the variation. In the case of the dents, the lowest mean is 3.84 temporary roots and the highest, 6.07, but in the one flint variety tested the lowest mean is 1.52 and the highest 3.69, the highest being just below the lowest dent ear. The average mean of the three dent varieties is very close, there being only 0.04 difference in the three. Plate I shows kernels of dent and of flint corn, the latter with one and the former with several temporary roots.

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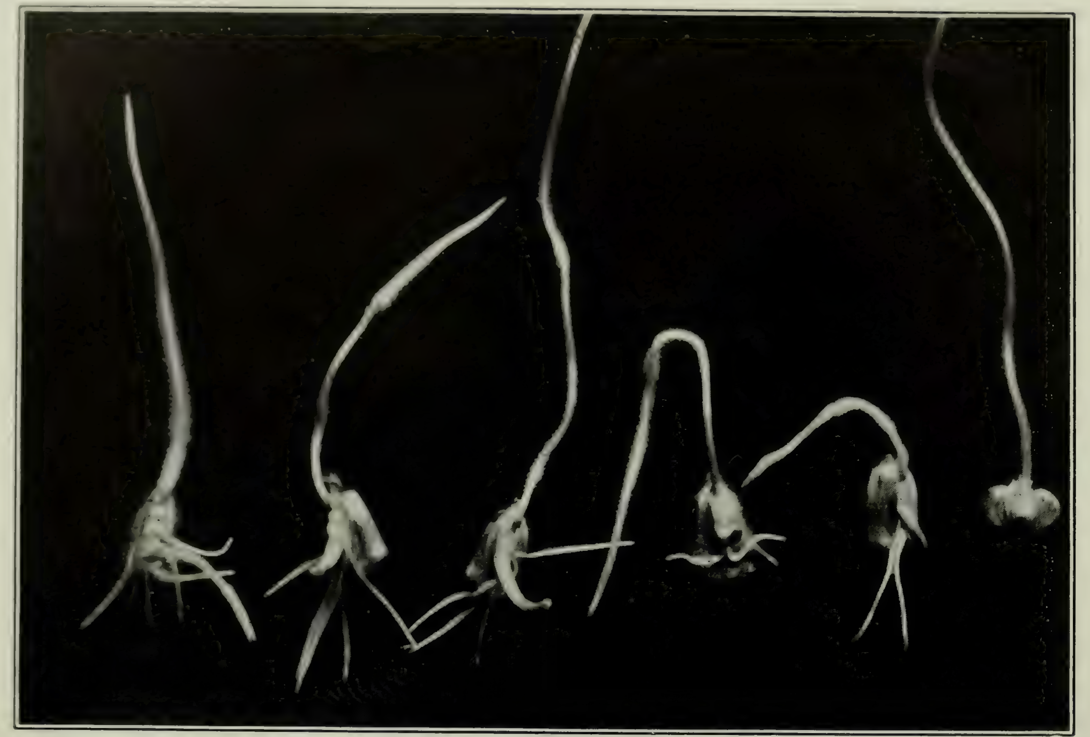

Kernels of dent corn, showing the number of temporary roots to be from three, the supposed typical number, to eight; also, at the right, a typical germinating flint kernel with only one temporary root.

TABLE 1.—*Number of kernels producing 1, 2, 3, 4, 5, 6, 7, 8, and more than 8 temporary roots in tests of 100 kernels each from individual ears of 3 varieties of dent and 1 of flint corn, with the total number germinating and the mean number of temporary roots produced by the kernels from each ear.*

REID'S YELLOW DENT.

Ear numbers.	Number of temporary roots.										
	1	2	3	4	5	6	7	8	Over 8.	Total.	Mean.
1	..	..	5	[a]40	27	7	..	..	..	79	4.46
2	1	..	9	34	23	13	5	1	..	86	4.64
3	..	..	..	24	17	20	20	8	1	90	5.71
4	..	..	7	20	10	6	..	..	..	43	4.35
5	..	...	11	48	17	8	1	..	..	85	4.29
6	..	..	7	48	9	15	5	3	..	87	4.68
7	..	..	14	39	22	10	2	2	..	89	4.47
8	..	..	12	50	15	3	2	1	..	83	4.23
9	..	..	5	53	18	9	1	..	..	86	4.40
10	..	3	12	44	16	12	2	1	..	90	4.47
11	..	..	3	29	35	13	3	3	..	86	4.92
12	..	..	13	44	23	8	..	..	..	88	4.52
13	..	..	22	42	17	4	1	..	..	86	4.07
14	..	..	1	60	13	10	4	1	..	89	4.09
15	1	..	10	50	15	7	1	..	..	84	4.11
16	..	1	13	32	17	7	4	5	..	79	4.61
17	1	..	3	23	25	17	13	3	1	86	5.27
18	..	..	3	21	17	14	4	2	1	62	5.08
19	..	..	..	9	16	35	19	9	1	89	6.07
20	..	..	12	40	21	10	3	1	..	87	4.48
Total..........	3	4	162	750	373	228	90	40	4	1,654	[b]4.58

JOHNSON COUNTY WHITE.

Ear numbers.	1	2	3	4	5	6	7	8	Over 8.	Total.	Mean.
1	..	..	19	38	12	7	1	..	..	77	4.13
2	..	1	8	42	15	11	2	2	..	81	4.51
3	..	1	10	53	10	6	1	..	..	81	4.16
4	..	..	12	40	15	11	2	1	..	81	4.43
5	..	..	10	43	17	6	2	1	..	79	4.37
6	..	..	8	26	32	14	5	..	..	85	4.79
7	..	..	2	27	19	12	2	..	..	62	4.76
8	..	..	15	54	10	8	..	..	..	87	4.13
9	..	..	10	34	11	8	..	..	..	63	4.27
10	..	..	2	14	11	4	..	..	..	31	4.55
11	..	..	10	32	18	2	..	1	..	63	4.26
12	..	..	3	26	19	19	7	1	..	75	5.05
13	..	..	5	47	9	8	2	2	..	73	4.47
14	..	..	2	34	22	6	4	..	..	68	4.65
15	..	..	3	48	13	10	2	..	..	76	4.47
16	..	..	1	37	21	16	4	2	..	81	4.89
17	..	..	4	16	8	1	..	..	..	29	4.28
18	..	..	7	36	15	9	2	..	..	69	4.46
19	..	..	2	16	19	24	14	8	..	83	5.68
20	..	..	10	42	15	9	..	..	..	76	4.30
Total..........	..	2	143	705	311	191	50	18	..	1,420	[b]4.54

PRIDE OF THE NORTH.

Ear numbers.	Number of temporary roots.										
	1	2	3	4	5	6	7	8	Over 8.	Total.	Mean.
1	..	..	8	**58**	13	5	1	..	..	85	4.21
2	..	..	10	**31**	5	..	..	..	..	46	3.89
3	..	..	5	**54**	13	10	2	1	..	85	4.45
4	..	..	1	**23**	21	10	6	3	..	64	5.13
5	..	..	11	**37**	23	6	1	..	1	79	4.41
6	..	..	4	**38**	22	4	3	1	..	72	4.54
7	..	..	6	**42**	19	20	..	..	..	87	4.61
8	..	..	4	17	**25**	15	7	3	..	71	5.18
9	..	..	1	**34**	24	13	3	1	..	76	4.84
10	..	..	8	**41**	19	14	..	1	..	83	4.57
11	..	..	16	**27**	15	3	..	..	..	61	4.08
12	1	..	3	**28**	17	12	2	1	..	64	4.70
13	..	..	8	**20**	14	16	6	..	..	64	4.72
14	1	..	16	**53**	5	1	..	..	..	76	3.84
15	..	..	1	**39**	31	15	1	..	..	87	4.72
Total..........	2	..	102	542	266	144	32	11	1	1,100	[b]4.54

FLINT.

Ear numbers.	1	2	3	4	5	6	7	8	Over 8.	Total.	Mean.
1	**43**	9	15	9	7	..	..	..	..	83	2.13
2	**23**	18	22	12	3	1	..	..	..	79	2.46
3	**37**	7	18	13	6	4	..	..	..	85	2.48
4	**25**	8	22	14	10	8	..	..	..	87	3.00
5	**44**	6	17	5	4	..	..	..	..	76	1.93
6	**14**	3	6	2	1	..	..	..	..	26	1.96
7	**53**	1	4	3	4	..	..	..	..	65	1.52
8	**26**	10	23	7	4	..	..	..	..	70	2.33
9	19	6	**20**	15	3	2	..	..	..	65	2.74
10	**24**	10	18	7	6	2	..	..	..	67	2.51
11	**21**	2	9	7	2	..	..	..	..	41	2.20
12	**26**	9	16	11	4	..	..	..	..	66	2.36
13	**32**	1	9	4	..	..	..	..	..	46	1.67
14	5	3	16	**20**	12	3	..	..	..	59	3.69
15	**30**	2	19	18	2	2	..	..	..	73	2.53
16	18	7	**24**	8	6	1	..	..	..	64	2.53
17	18	14	**22**	11	3	..	..	..	..	68	2.52
18	**30**	5	6	4	..	..	..	..	..	45	1.64
19	**24**	13	17	9	2	..	..	..	..	65	2.26
20	12	12	**17**	9	1	1	..	..	..	52	2.58
Total..........	524	146	320	188	80	24	..	..	..	1,282	[b]2.32

[a] Maximum frequencies in boldface type.

[b] Average mean.

In Table 2, which is a summary of Table 1, the results are given on the percentage basis. The class in which the greatest percentage falls is the one with four temporary roots (it will be recalled that the radicle is included) in the case of the dents, but the one flint variety tested gave the greatest percentage with only one temporary root, this of course being the radicle. Considering the individual ears of the flint variety, there are only five exceptions to the rule that the mode is the class with one temporary root. Four of these exceptions have the greatest number of kernels with three temporary roots and one with four. It is also noticeable that there is a small percentage in the case of the flint with only two temporary roots.

TABLE 2.—*Percentages of total number of kernels which produced 1, 2, 3. etc., temporary roots in each of 3 varieties of dent and 1 of flint corn.*

Number of temporary roots.	Variety.			
	Reid's Yellow Dent.	Johnson Co. White.	Pride of the North.	Flint.
	Percent.	*Percent.*	*Percent.*	*Percent.*
1	0.18		0.18	40.88
2	.24	0.14	.....	11.38
3	9.79	10.07	9.27	24.96
4	45.34	49.64	49.27	14.66
5	22.55	21.90	24.18	6.24
6	13.18	13.45	13.09	1.88
7	5.44	3.52	2.91	
8	2.42	1.27	1.00	
Over 8	.24	.....	.09	

In Table 3 the results of a test with three other varieties of flint corn are given. The figures in this table show even a more marked difference between the flints and the dents. Five hundred kernels were taken from shelled samples of these varieties for the test as explained above; thus, of the flints alone 4,500 kernels were tested.

TABLE 3.—*Percentages of the total number which produced 1, 2, 3, etc., temporary roots of 500 kernels each in tests of 3 varieties of flint corn, in the 20 individual ears reported in Table 1, and in all flint corns tested, with the mean number of temporary roots for each variety.*

Number of temporary roots.	Variety.				Average.
	Unknown.	Hall's Gold Nugget.	New York Flint.	20 ears reported in Table 1.	
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*
1	84.05	60.72	98.88	40.88	71.13
2	4.64	18.38	.28	11.38	8.67
3	8.41	15.45	.56	24.96	12.35
4	2.32	2.42	.28	14.66	4.92
5	....	2.12	....	6.24	2.09
6	.29	.91	....	1.88	.77
7	.29	....	....	....	.07
Mean.........	1.32	1.70	1.02	2.40	1.61

Table 4 gives a similar summary of tests made with seven varieties of sweet corn. Here, too, the greatest percentage of the kernels germinating show the development of but a single temporary root.

TABLE 4.—*Percentages of the total number which produced 1, 2, 3, etc., temporary roots in tests of 500 kernels each of 7 varieties of sweet corn, the average for all varieties, and the mean number of temporary roots for each.*

Number of temporary roots.	Variety.							Average.
	Unknown.	Country Gentleman.	Howling Mob.	Crosby's Early 12-row.	Early Minnesota.	Queen's Golden.	Mexican Black.	
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
1	30.00	53.68	24.80	20.65	20.80	38.74	69.34	36.86
2	8.75	16.24	18.17	11.23	10.54	11.54	10.95	12.49
3	21.25	18.72	22.31	30.44	23.37	29.40	11.68	22.45
4	18.75	8.38	24.80	26.45	31.63	16.20	5.84	18.87
5	17.50	2.49	7.44	8.70	9.40	3.57	1.46	7.22
6	3.75	.49	2.48	2.17	3.70	.55	.73	1.98
7	....	....	....	.36	.56	....	....	.13
Mean....	2.94	1.91	2.79	2.99	3.12	2.40	1.61	2.54

Tests made with the limited quantity of pop corn available indicate that its germination is very similar to that of the dent corns, but the soft corn tested showed the greatest variation between ears and also within the individual ear. One ear had the greatest percentage with one temporary root, while another gave the greatest percentage with six temporary roots.

TABLE 5.—*Number and percentage of the total which produced 1, 2, 3, etc., temporary roots in tests of 200 kernels each of 5 types of wheat and 1 each of einkorn and emmer, the total number which germinated, and the mean number of temporary roots for each.*

Number of temporary roots.	Durum.		Soft winter.		Hard winter.		Polish.		Red winter.		Einkorn.		Emmer.	
	Number.	Percent.	Number.	Percent.	Number.	Percent.	Number.	Percent.	Number.	Percent.	Number.	Percent.	Number.	Percent.
1	..	...	1	.71	..	...	..	...	..	...	..	...	..	...
2	3	3.95	5	3.55	3	1.97	..	...	..	...	4	3.45	..	...
3	17	22.37	24	17.02	29	19.08	6	7.23	3	9.38	39	3.362	..	...
4	25	32.89	35	24.82	56	36.84	8	9.64	12	37.50	11	9.48	8	6.40
5	30	39.47	53	37.59	60	39.47	50	60.24	14	43.75	60	51.73	90	72.00
6	1	1.31	23	16.31	4	2.63	19	22.89	3	9.38	2	1.72	26	20.8
7	..	...	..	...	..	...	..	...	..	...	..	...	1	.8
Total.	76	...	141	...	152	...	83	...	32	...	116	...	125	...
Mean..	4.12	...	4.44	...	4.22	...	4.09	...	4.53	...	4.15	...	5.17	...

Table 5 gives the results of a preliminary test with several groups of wheat and also with einkorn and emmer. The germinating percentage was very poor in all cases. Two hundred kernels were used in each test. It is very noticeable that in the wheat types, without a single exception, the greatest percentage and in some cases the majority of kernels produced five temporary roots.

The results here reported may not be absolutely conclusive because the tests were not carried out under natural conditions, germination taking place under almost optimum conditions. In the soil, adverse conditions would be met in many instances. Likewise it is possible that the heating which the seed received and also the age influenced to some extent the temporary root development. The necessary variation in the time of counting may have had something to do with the results, but the flint and sweet corns remained longer in the tester than the others, as additional temporary roots were expected to develop.

In all cases, the radicle first appeared, followed by the plumule. If more roots developed, a pair appeared just beneath the plumule, while others grew from any portion of the primary node (the point of union between the plumule and radicle and the embryo).

SUMMARY.

1. The results here reported indicate that the various groups of corn and of wheat do not have a regular number of temporary roots and it is doubtful if any one has a definite number in even a majority of cases.

2. The dent corns have four temporary roots in a greater percentage of cases than any other number, as do also the pop corns which were tested.

3. The flint and probably the sweet corns have one temporary root in more cases than any other number.

4. The soft corns vary greatly in all cases in the number of temporary roots produced.

5. In the various groups of wheat, the greatest percentage produces five temporary roots, instead of three as is ordinarily reported.

THE PREPARATION OF MATERIAL FOR FIELD CROPS LABORATORY.[1]

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Introduction.

Laboratory work in agriculture in colleges and high schools may be conducted very easily and efficiently when plenty of material is available, but is very unsatisfactory when thêre is a limited supply of poorly prepared specimens at hand. This is no less true of the work in field crops than in any other phase of agricultural work. A soil laboratory can be made very attractive and be well equipped for student work with a supply of the common soil types and the apparatus which is necessary for studying the various properties of soils, but not so with the field crops laboratory. A crops laboratory should be equipped with well prepared specimens of all the crops to be studied. These should be well labelled and placed in such a way as to make the rooms as attractive as possible. Students will gain a great deal of knowledge of the appearance and nature of plants by merely seeing them displayed for a time. It is well to have some of these specimens so mounted that they may be taken down and used for class work.

A study of this problem has been made at the Montana State College for the past three years, where the growing season is so short that outdoor work during the school year is very limited. This necessitates, as it does in many localities, the fitting up of the laboratory so that a rather complete study of crops may be made indoors.

Many schools are making use of mounted material which is prepared and sold by educational institutions and supply houses. This material, while very good, is unsatisfactory from two standpoints: (1) In many cases the specimens do not meet the local needs, and it is impossible to obtain varieties of local importance; and (2) the distinguishing features of the plants are not always preserved; that is, the leaves and roots are not mounted in the best manner.

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[1] Received for publication July 20, 1915.

COLLECTION OF MATERIAL.

The season which is most satisfactory for collecting plants for mounting varies considerably with different localities. In the Northern states, July and August seem to be the most suitable months for collecting. Some collecting may be done by students after school opens in September, and this is to be encouraged in localities where it is possible.

As pointed out by Derr and Lane,[2] two classes of material should be collected: (1) Specimens for permanent mounts, which are to be used for museum purposes and illustrative work in class; and (2) material which is to be used for detailed and experimental work in class. The specimens which are intended for the former purpose must of necessity be carefully selected and be typical as far as possible, while that for the latter must be gathered in larger quantities and need not be so carefully selected. This bulk material should be tied in small bundles and hung up to cure. The stage of maturity at which leguminous and other plants of a similar nature should be collected is when they are in full bloom. The grass-like plants are most successfully collected when they are more mature, but before the leaves become discolored to any extent. Where merely the heads of grains and grasses are desired, it is preferable to allow the plants to ripen before collecting, but discoloration by weathering should be avoided.

The collection of root specimens is best accomplished by growing the plants in deep, narrow boxes set into the soil. The boxes may then be taken up and the soil washed out by means of a stream of water. Shallow roots may also be obtained by digging up a portion of the soil with plants which have grown in the field, and washing the soil away from the roots. The best roots are obtained a short time before the plants mature.

PRESSING MATERIAL.

The material which is intended for mounting, except the specimens of ripe heads, should be pressed carefully so it will retain the natural shape as nearly as possible. The most satisfactory way of pressing these specimens is to place them carefully on sheets of heavy paper and fasten in place with small strips of transparent adhesive tape such as is used for repairing books, music, etc. These are then placed between large sheets of blotting paper and pressed. The pressing may be done in a regular plant press, or if this is not available, the pressure may be applied by placing sacks of grain on the blotters. If the plants have large stems or roots, pressing by means of the sacks of grain is better as the leaves and other thin portions of the plants are pressed more firmly. The best results are obtained where the blotters are replaced with dry ones a few times, though this is not always necessary.

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[2] Derr, H. B. and Lane C. H., Collection and Preparation of Plant Material for Use in the Study of Agriculture, U. S. Dept. Agr. Farmers' Bul. 586: 1–24. 1914.

Preparing Mounted Material.

The most suitable and the only permanent way of preserving pressed material so it is available for exhibit purposes and for student use is to place it behind some kind of transparent covering. The cheapest and most satisfactory covering that has been found is transparent celluloid. Glass was tried, but it proved too easily broken and made the mounts too cumbersome. The suggestion as to the use of celluloid was obtained from the departments of plant breeding and plant pathology of Cornell University, where a large amount of celluloid is used for various purposes.

The backs of the mounts should be made of some rigid material which will not warp. Beaver-board and heavy bristol-board were both tried for this, but were discarded because they warped too readily. Compoboard, which may be purchased from most lumber dealers at about 4 cents per square foot, has given the best satisfaction.

The steps in making a mount of a pressed plant are as follows:

1. Cut out a piece of compoboard of the desired size.
2. Place two thicknesses of white cotton wadding on the board.
3. Cut out a piece of drawing paper for label and paste to a heavy strip of bristol-board as shown in Plate II, figure 1. The labelling may be done with India ink or black paper letters; the former is to be preferred. Small disks may be cut out of this bristol-board and samples of seed inserted as shown in the lower left-hand corner of the mounts.
4. Carefully remove the plant from the sheet on which it was pressed and place on the cotton wadding. In some cases it is well to fasten the plant to the cotton with library paste.
5. Cut a piece of transparent celluloid the same size as the mount and place it over the plant.
6. Tack down the celluloid at the corners with 2-ounce tacks. Rule off a space three-eighths of an inch wide around the edge of the celluloid and sandpaper well so that the tape will adhere. Tack the celluloid well around the edges and bind with passepartout tape 1 inch wide.

The cost of mounts prepared in this way is very slight. The material used in the preparation of a specimen such as is shown in Plate II, figure 1, approximates 14 cents.

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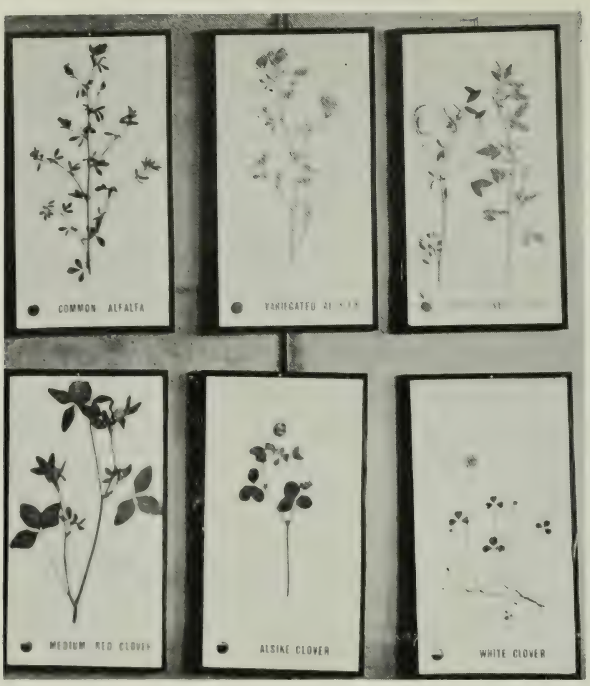

FIG. 1. Mounted specimens of alfalfas and clovers.

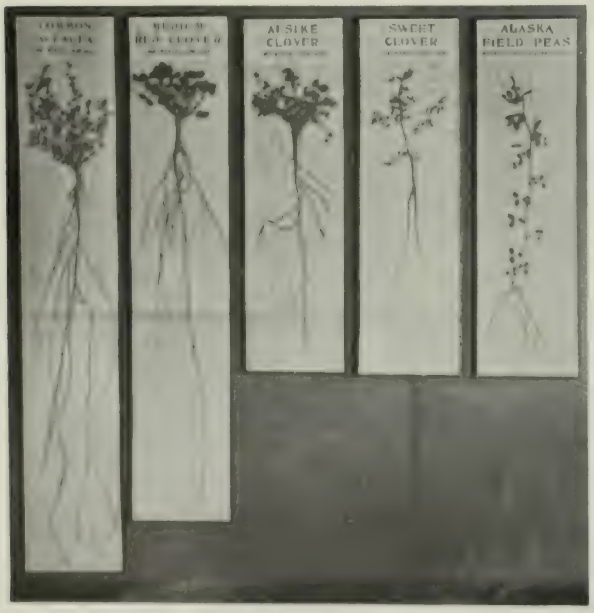

FIG. 2. Specimens of leguminous plants mounted to show root development.

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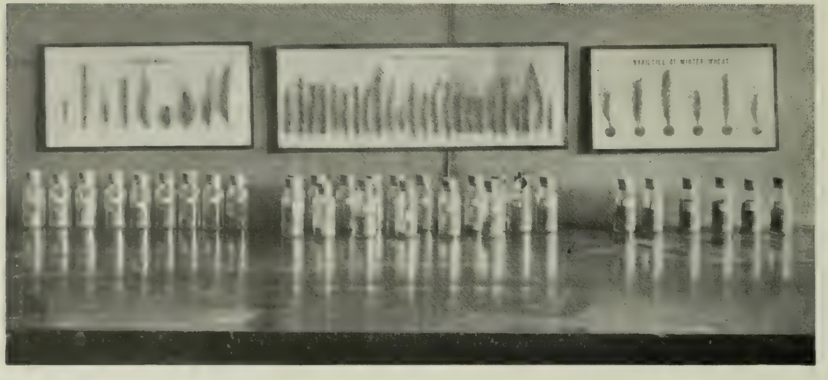

FIG. 1. Mounted specimens of heads and thrashed samples of grain for the study of groups and varieties of wheat.

MODEL EXERCISE
FIELD CROPS LABORATORY

FIG. 2. Chart used as model exercise in field crops laboratory (after Lyon and Montgomery).

Some of the mounts which were prepared in the above manner are shown in Plate II. The mounts shown in Plate II, figure 1, are 10 by 18 inches, while those in figure 2 are 10 inches wide and vary from 3½ to 5½ feet in length. The lettering is outlined by means of rubber stamps and then inked in with India ink.

The method of mounting the ripened heads of grains and grasses is illustrated in Plate III, figure 1. These are similar to the mounts of the pressed plants except that there are several heads in each mount. These heads are attached to bristol-board by means of fine copper wire and then placed on the compoboard. Small disks may be cut out of the bristol-board and samples of thrashed grain placed in them as illustrated. The individual heads may be labelled with typewritten slips or lettered by hand. Ten inches is found to be a very convenient width for this type of mount. They may vary in length according to the number of heads in the mount.

When these mounts are accompanied by bottles of the thrashed seed, as illustrated, they prove very useful in the study of types and varieties of the cereals. The characteristics of the different cereals are best studied from specimens which the student may dissect.

A model exercise which is very helpful in obtaining uniform arrangement of work in students' notebooks is shown in Plate III, figure 2. This is drawn on ordinary sign cloth, mounted on compoboard, and covered with celluloid. The size of this chart is 30 by 36 inches, so that it may be easily seen from all parts of the room.

The illustrations show only a few of the mounts that have been found helpful in laboratory instruction. Varieties and types of corn are very easily exhibited by placing longitudinal and cross-sectional views of the ear in black wooden boxes 6 inches wide, 12 inches long, and 2 inches deep. These specimens are fastened in by means of fine copper wire. The front of the boxes is then enclosed with celluloid. About fifty varieties of corn have been mounted in this manner, and these together with the bottles of shelled corn are used in the study of varieties.

Thus it may be seen that all of our field crops may be preserved in a permanent way so that they form a very attractive museum and at the same time may be used for instructional work. The field crops laboratory at the Montana State College is now equipped with about 200 permanent mounts which have been prepared at small expense.

SOILS COURSES AT THE IOWA STATE COLLEGE.[1]

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Prior to 1902, the soils work at the Iowa State College consisted of one brief course in soil physics. In that year the work was more definitely organized as a subdivision of the Agronomy Department and Professor W. H. Stevenson was placed in charge. Four distinct courses were then outlined by Professor Stevenson: Soil physics, soil fertility, special problems in soil physics, and special problems in soil fertility. In this early work general principles governing soil physics and fertility were taught and emphasized by laboratory experiments and special problems involving some original investigations, either from the physical or fertility standpoint, were assigned.

These four courses in soils have formed the foundation upon which has been erected the structure of the present work in soils. Professor Stevenson has since become professor of agronomy and vice director of the agricultural experiment station, but he has always retained an active interest in and close association with the soils work. Much of the advance which has been made in the arrangement and teaching of the soils courses is due to his continual devotion to the work and to his untiring efforts to give students a thorough understanding of all the principles underlying soil fertility in its relation to permanent agriculture.

In response to the demand for more thorough training in soils and in accord with the increasing mass of knowledge regarding soils which has been accumulated from such a variety of angles, the original four courses have been added to, until now some thirty-odd courses in soils are required of or offered to undergraduate and graduate students in agriculture at this institution. Five more or less distinct groups of soils courses are now recognized, depending upon the particular factor which receives the emphasis in the work. These groups are soil physics, soil fertility, soil bacteriology, soil surveying, and soil management. Undergraduate and graduate courses have been outlined under these headings which involve quite distinct work.

The soil management work is presented by Prof. Stevenson, the

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[1] Received for publication October 6, 1915.

courses in soil physics, soil fertility, and soil surveying are under the immediate charge of Prof. R. E. Smith, associate professor of soils, while the soil bacteriological courses are given by the writer. The purely undergraduate courses in soil physics, fertility, and bacteriology are probably of the greatest interest, because they are required of all agricultural students and because they are given according to a rather definite plan. Special problems courses and research courses must always of necessity be outlined for each individual case, and no fixed plan can be followed.

The methods employed in presenting to the undergraduate the subject of soils from the physics, fertility, and bacteriology standpoints are quite different from those in use elsewhere, at least so far as the laboratory work is concerned. For this reason and also because they have attracted much favorable attention, it has seemed desirable to present a rather brief outline of the work.

The regular courses in the three subjects mentioned consist of two lectures and four hours' laboratory work per week during one semester. Text-books are employed only as support for the lecture work and serve more as reference books than as texts, although the student is expected to familiarize himself with material contained in the assignments as well as with that presented in the lectures.

The laboratory work is so arranged that each student is given the opportunity to examine two soils from his own home farm, to study their physical, chemical, and bacteriological properties, and to draw rather definite conclusions from his results regarding the methods of treatment which should be followed to maintain each soil permanently fertile. Students who are not able to secure samples of soil from their own farm or from a farm in which they are particularly interested are supplied with two samples taken from the college experimental fields or from some farm in the vicinity. Each student thus works with special soils different from those used by any other student. These are soils in which he is particularly interested and accuracy in securing results is eagerly sought, for it is clearly recognized that the conclusions drawn—that plan outlined for permanent fertility of the soils—depends entirely upon the care used in the work and the interpretation of the results.

Not only is the student allowed to choose the soils which he studies, but he may also select the system of farming in which he is particularly interested and interpret his results from the livestock-farming, grain-farming, dairy-farming, truck-farming, or orcharding standpoint. The actual laboratory work involved is somewhat different for each system of farming, but the problem is the same in every case. All data necessary for the working out of systems of permanent fertility which time will not permit the student to secure for himself are supplied by the instructor from average analyses.

The same soils are studied in each of the three courses, and at the end of each course a report is required showing the needs of the soils and making definite recommendations for treatment according to one of the systems of farming mentioned. At the conclusion of the work in the three courses, which are given in the order of soil physics, soil fertility, and soil bacteriology, a complete report on the tests of the soils from the three angles is required and a comprehensive statement regarding their physical, chemical, and bacteriological needs from the permanent fertility standpoint is prepared.

The investigation of the special soils in the soil physics laboratory considers first the geology of the area from which they come, with a view of determining their origin and formation. A complete mechanical analysis is then made, which is followed by a classification of the soils according to type.

The various physical properties of the two soils which are studied include a determination of the hygroscopic moisture, the true and apparent specific gravity, the pore space, the rate of absorption, the flow of water and air through the soils, the organic matter content, the effect of added organic matter on the water-holding capacity and other physical properties of the soils, and the effect of lime on the structure and physical conditions of the soil. From the data secured by these tests, conclusions may be drawn regarding the best treatment of the soils with regard to regulation of the moisture content through drainage, cultivation, mulching, etc., the plowing, harrowing, and cultivating as affecting the general physical conditions of the soil, the need and effects of manuring and liming the soils, and the physical effect of different systems of rotation and cropping.

The fertility experiments in the laboratory are arranged with the view of enabling the student to secure the data which he needs to work out the method of treatment of the soils which should be followed to maintain them permanently fertile.

In the first place, he must analyze his soils for total nitrogen, total and available phosphorus, acidity, and lime requirement. Iowa soils are not deficient in potassium, so that element is not determined except in special cases. A sample of grain or fodder is analyzed for nitrogen and phosphorus to determine the amount of plant food removed from the soil by crops. Barnyard manure or green manure, a phosphate and a complete fertilizer, are likewise analyzed to ascertain the return of plant food made possible through the use of these materials.

Some one of the systems of farming previously enumerated is then chosen and the maintenance of fertility in each soil under that particular system is considered. Thus the plant-food content of the soil is determined, the amount removed by crops is calculated from data secured or supplied from average analyses, the loss from the farm through the sale of products is ascertained, and the return by yard manure, green manure, etc., is estimated. The addition of necessary constituents in fertilizing materials is ascertained and the cost of the fertilizers, the value of the manure produced, and the income from grain, livestock, truck crops, dairy products, or fruit is calculated.

A method of treatment of the soil which will maintain the store of plant food under the particular system of farming and at the same time prove practicable from the economic standpoint is then worked out. In short, a plan of farming which will prove practical, profitable, and permanent is outlined for each soil. These plans often prove of great value to men after they return from college to their own farms and take up in earnest the business of farming.

The samples of soil examined in the laboratory work in soil bacteriology are secured by the student from his home farm whenever possible, just as in the case of the tests from the physical and fertility standpoints. Large samples are obtained at the beginning of the work and are air-dried to serve as the medium for the carrying out of some of the tests, and fresh samples are obtained two or three times during the course to supply the material for inoculation. The tests are so arranged that a number may be inoculated at the same time, using the same fresh soil. The soils are examined for their total content of bacteria, using several of the better media. The ammonifying power is tested by the peptone solution method and by the dried-blood air-dried-soil method. The nitrifying power is determined by the solution and soil methods, and similarly the denitrifying or deazotofying power and the non-symbiotic nitrogen-fixing or azofying powers of the soils are determined by the two methods. The cellulose-destroying power of the soils is tested, and the effects of lime, magnesia, and organic matter on the ammonifying and nitrifying powers of the soils are determined. Finally, the organisms producing the inoculation of legumes are isolated and described and comparisons made of those secured from different sources.

Upon the completion of these tests, a report is prepared showing the relative bacterial efficiency of the different soils from the standpoint of total numbers, nitrogen-transforming and fixing powers, and organic-matter decomposing power.

When the three courses described above are completed, a complete report on the two soils examined is prepared from the physical, fertility, and bacteriological standpoints. The material thus secured, besides emphasizing in a very complete way the principles underlying soil fertility, may actually prove extremely valuable to the student in aiding him to solve the problems of soil management which continually arise on the farm.

A course in soil management consisting of lectures alone is required of all agricultural students, and the general broad principles governing the management of soils under all conditions are definitely presented.

Special courses in soil physics are outlined for students specializing in horticulture and in forestry, and the outline of the regular course given above is modified somewhat to meet the needs of these groups of students.

The special problems courses in soils are outlined along the various lines mentioned and are offered as elective work. They may be followed by and closely linked up with the thesis work in soils. A wide variety of problems is presented to the student and he is allowed to choose a problem which appeals to him. Laboratory, greenhouse, and field studies are included in this work and considerable valuable data are accumulated by careful students who specialize in soils work.

These special problems courses and also the thesis work in soils require some original investigational work. In other words, the student must actually carry out the work and draw his conclusions from the results obtained. It is believed that these courses prove of much greater value to those taking them than if they were experimental in name only and students were allowed, as is too often the case in thesis work, to obtain credits merely by presenting a review of the investigations of others.

Research or graduate courses in soils are offered along the same lines as those followed in the undergraduate work. These courses consist naturally of definite problems for the individual student. Experimental work is outlined along some line which appeals strongly to the student, and at the conclusion of the work he presents a thesis which must be acceptable as a part of the requirements for an advanced degree. A very wide variety of problems may be studied by graduate men, and the facilities are such that it is possible to secure quite complete and entirely satisfactory results for publication.

A feature of the graduate work in soils is the conference courses. These have been found to be of very great value to graduate men. Reference and report work on investigations along special and general lines is required which serves admirably to place the student in close touch with past experiments, to give him a thorough insight into methods of experimentation, and to convey suggestions which may be of great value to him in carrying out his own work.

The laboratory, greenhouse, field, and library facilities for work along soils lines are excellent, and the work accomplished is evidence of the good use of all the facilities available. The large interest in soil work and the strong appreciation of strong, helpful courses in soils, as expressed by both undergraduate and graduate students, serve both as an incentive and a reward to those who have labored and are laboring to present soils work thoroughly, to stimulate interest along soils lines, to encourage and direct the experimental tendencies which are so characteristic of many students, and finally to aid in the development of the proper agricultural practices by graduating men who know the needs of soils and how to meet those needs, and who also have firmly instilled into them the fact that permanent agriculture is closely dependent upon the maintenance of soil fertility.

THE AVAILABILITY OF NUTRIENT SALTS.[1]

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Scientific workers everywhere have always found difficulty in correlating the chemical analysis of the soil with the crop yields obtained in the field from the use of fertilizers. Indeed, the one vital problem which has occupied the attention of agricultural chemists for more than half a century has been the correlation of their results with those obtained by pot, plot, and field cultures. In spite of all of these efforts, the agronomist is yet unable to get from chemical analyses anything that will be of great value to him in the feeding of his plants.

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[1] Contribution from the Laboratory of Plant Physiology, Johns Hopkins University. Received for publication July 6, 1915.

Elaborate studies of the soil solution have resulted in disappointment because of the fact that while it has been admitted that the adsorbed layer at the immediate surface of the soil grains is of different concentration from that of the mass of free solution, it appears that no method has been devised for determining this difference in the concentration. Furthermore, no direct experimental evidence has been reported that would throw light upon the question of the availability and the nonavailability of the adsorbed layer. It has been shown with a reasonable degree of certainty that in many cases the thickness of the adsorbed layer is less than that of the layer of outside cell walls which covers the absorbing protoplasm in the root. From this it is argued that since the protoplasm does not come into contact with the adsorbed layer the latter must therefore be unavailable except for the possible slow diffusion of the salts from the adsorbed layer out into the adjacent free water film. As a further support for the theory that the adsorbed layer is not available, it is pointed out that in field practice the addition of a few pounds of soluble potash to an acre foot of soil, for instance, will often produce a very decided increase in growth of crop, although there may be present in the upper foot of soil as much as 20,000 pounds of potash.

Jensen[2] has shown that the introduction of pure quartz flour into a toxic solution reduces its toxicity to a marked degree. He states, however, that it is an open question whether the reduction in toxicity is due to adsorption, to a reduced freedom of movement of the solute particles (that is, a reduction of the diffusion tension), or to some chemical changes produced by the presence of the fine quartz particles. By repeating in sand cultures some of the recent water culture work of Shive[3] the writer has found some very direct evidence that the presence of the sand results in the removal of some of the nutrient salts, thus serving to show that the adsorbed layer is not available for the use of the plant. Shive grew winter wheat for a period of 24 days in a 3-salt nutrient solution which was renewed at the end of each 3-day period. His cultures were divided into three series, each of which had the same total concentration. A suboptimal series had a total osmotic concentration of 0.1 atmosphere, an optimal a concentration of 1.75 atmospheres, and a supraoptimal a concentration of 2.5 atmospheres. Each series consisted of 36 cultures each of which contained the three salts in different proportions.

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[2] Jensen, G. H., Toxic Limits and Stimulation Effects of Some Soils and Poisons on Wheat. Bot. Gaz., 43: 11-44. Jan., 1907.

[3] Shive, J. W., A Three-Salt Nutrient Solution for Plants, Amer. Jour. Bot., 4: 157-160. April, 1915.

Using seed from the same lot as was employed by Shive in his solutions, the writer has repeated in sand cultures his optimal series which had a total osmotic concentration of 1.75 atmospheres. To make the conditions in the sand cultures comparable with those in the solutions, it was necessary to devise a means by which the nutrient solution in the sand could be renewed at the end of each 3-day period. This renewal was accomplished by means of a hemispherical funnel which projected through the wax seal covering the surface of the sand and a small tube sealed into the pot at the bottom. Every three days the solution was renewed by flushing the pots with a fresh nutrient solution, which was poured in through the funnel at the top while the solution was being removed at the bottom by suction applied to the tube opening into the interior. Previous to each renewal of the nutrient solution sufficient distilled water was added to each pot to replace the water lost by transpiration and thus bring the solution back to its original concentration. A detailed account of this new sand culture method will be found in a separate paper which has already appeared in the JOURNAL OF AGRONOMY.[4]

The series of sand cultures in which the solution used had a total initial osmotic concentration of 1.75 atmospheres gave relative weights of tops almost identical with those obtained by Shive in his suboptimal water culture series which had a total osmotic concentration of 0.1 atmosphere. Shive's solution giving the best growth of wheat tops contained the three salts in the following volume-molecular partial concentrations: KH_2PO_4, 0.0180 m.; $Ca(NO_3)_2$, 0.0052 m.; $MgSo_4$, 0.0150 m., while the best solution in the sand culture had volume-molecular partial concentrations of KH_2PO_4, 0.0072 m.; $Ca(NO_3)_2$, 0.0182 m., and $MgSO_4$, 0.0050 m. Attention is called to the fact that not only is there a wide variation in the total osmotic concentration of the solutions in the two cases but the ratio of magnesium to calcium is also decidedly different for the best individual cultures in the water cultures and in the series in sand. In the former the ratio is 1 : 029, while in the latter it is 1 : 2.88. A comparison of the results from the two series, the one grown in water and the other in sand cultures, furnishes evidence for the following conclusions: (1) That the concentration of the nonadsorbed solution in the sand is markedly lower than that of the solution which was added; (2) that the adsorbed salts are either nonavailable or are very greatly retarded in their participation in the growth process of the plant; and (3) that for this particular concentration the ratio of magnesium to calcium ions in the optimum nutritive solution is materially changed by the adsorption process.

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[4] McCall, A. G., A New Method for the Study of Plant Nutrients in Sand Cultures, JOUR. AMER. SOC. AGRON., 7: 249–252, 1915.

DETERMINATION OF CELL SAP CONCENTRATION BY THE FREEZING POINT METHOD.[1]

George J. Bouyoucos and M. M. McCool.

It has been discovered that the freezing-point method can be used to determine the concentration of the soil solution directly in the soil from any maximum down to a very low minimum moisture content. The results yielded by this method are really revolutionary as far as the concentration of the soil solution is concerned. These data have been reported elsewhere.[2]

In the present note it is desired to call attention to the fact that as a result of its successful application in the aforesaid study the freezing-point method can now be used to investigate many other problems. The results of these studies probably will be as surprising as those of the concentration of the soil solution in the soil. One of these problems that may be mentioned at this time is the determination of the concentration of the plant cell sap. Instead of extracting the cell sap to determine its lowering of the freezing point and consequently its concentration, the latter can be ascertained directly in the plant. This can be accomplished by crushing the plant tissue, placing it in the freezing tube, inserting the thermometer, and following the procedure as described in the bulletin already cited. Considerable work has already been done upon the subject, and the results obtained have fulfilled the anticipation, namely, the concentration of the cell sap is greater when determined directly in the plant than in the extracted cell sap. (Michigan Agricultural Experiment Station, East Lansing, Mich.)

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[1] Received for publication January 13, 1916.

[2] Bouyoucos, George J., and McCool, M. M., The Freezing Point Method as a New Means of Determining the Concentration of the Soil Solution Directly in the Soil, Mich. Agr. Expt. Sta. Tech. Bul. 24, 1916.

MICELLAR EMULSIONS AND HYDROGELS OF OIL.[1]

Karl F. Kellerman and Walter T. Swingle,

Bureau of Plant Industry, U. S. Department of Agriculture,
Washington, D. C.

It has been found that aqueous solutions and emulsions of oils for use as insecticides, fungicides, and germicides may be prepared with great ease by utilizing the solvent and emulsifying action of cresylic soap liquors manufactured by combining para-, meta-, or ortho-cresylic acid, or crude cresol,[2] with soap formed from oils, fats, resins, or waxes, and alkali. "Liquor cresolis compositus" of the U. S. Pharmacopoeia, 8th edition, 1905,[3] is an example of a cresylic soap liquor of a suitable composition, though a slightly more satisfactory formula is secured if the quantity of the cresol is reduced from 500 grams to 300 grams.

These cresylic soap liquors are capable of dissolving large quantities of hydrocarbon oils, carbon bisulfid, carbon tetrachlorid, chloroform, and many other substances but slightly soluble in water. An almost clear solution results upon dilution with water provided small proportions of the oil or other substances are dissolved in the cresylic liquor; if a larger proportion of the oil or other substance is dissolved in the liquor, the addition of water produces an emulsion instead of a clear solution; if too large a proportion of the oil or other substance is dissolved in the liquor and water is added, the emulsion breaks down rapidly. For example, one part of liquor cresolis compositus is able to carry one or even two parts of kero-

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[1] Received for publication July 16, 1915.

[2] The elimination of xylinols from crude cresol, as practiced by Raschig (*see* Schürmeyer, B., *in* Archiv. f. Hygiene, 25: 333, 1895) is unnecessary. Empirical tests show that considerable quantities of 1:3:4 and 1:4:5 xylinol slightly increase the oil-carrying capacity of the mixtures. The presence of unsubstituted phenols in appreciable quantities, however, lowers slightly the solvent and emulsifying powers.

[3] Additional information as to the best methods of preparation is given by Chas. H. La Wall and E. Fullerton Cook, Liquor Cresolis Compositus, *in* Amer. Jour. Pharm. 78: 169–172, 1906, and also by McBryde, C. N., The Germicidal Value of Liquor Cresolis Compositus, U. S. P., U. S. Dept. Agr., Bur. An. Indus. Bul. No. 100, 1907.

sene oil in solution and still make a clear solution when diluted with water, though the viscosity of the liquid is slightly increased;[4] if from three to seven parts of kerosene are mixed with the cresylic soap liquor, permanent emulsions are formed upon dilution; and, finally, if at ordinary summer temperatures (70° to 90° F.) 10 or more parts of kerosene are added to the liquor cresolis compositus, the addition of water causes much of the oil to separate from the emulsion.

The emulsion resulting from the addition of water to the combination of proper quantities of oil and cresylic soap liquor is in a remarkably fine state of subdivision. It is not an emulsion formed by the ordinary process, the mechanical subdivision of large oil drops. Instead, it is produced from a solution of oil in a cresylic soap liquor by dilution with water, whereby excessively minute particles of oil are forced out of solution and form all through the liquid. Such an emulsion may be called a micellar emulsion because of the excessively small size of the oil droplets. If properly made, it is permanent, the oil showing no tendency to separate. The essential point in this system is the convenient and rapid production of solutions, hydrogels, or permanent emulsions of kerosene or other hydrocarbon oils and certain other substances by combining them with a cresylic soap liquor, of which liquor cresolis compositus is an example.

The power of cresylic liquor to form clear hydrogels is greatly enhanced by the addition of a small quantity of glycerin. The glycerinated cresylic liquor after the addition of hydrocarbon oils, carbon tetrachlorid, or other substances slightly soluble in water, may then be diluted with from 1 to even as much as 20 parts of water and still form a clear jelly-like substance.

A great variety of formulas of the character outlined below are efficient both as germicides and fungicides as well as insecticides. Extensive experiments with these mixtures upon date palms and some preliminary tests on other plants have been made. These tests are sufficient to indicate that the formula outlined below is a standard from which deviation may be made in the proportion of any or all of the ingredients, depending upon the nature of the plant or other object which it is desired to spray, the climatic conditions under which the spraying is to be undertaken, and the salt content of the water with which the mixtures are to be diluted. One part of cresylic soap liquor is mixed with three to seven parts of kerosene or other light hydrocarbon oil. This mixture is then diluted with pure water or with water containing small percentages of pyridine, formalin, metallic salts, or sulfids of sodium, potassium, or calcium. Small quantities of turpentine or carbon bisulfid, carbon tetrachlorid, or chloroform may be added to the hydrocarbon oil before mixing with the cresylic liquor. These mixtures should be diluted with water in suitable proportions, depending upon the salt content of the water, the temperature, the character of the diseased or infected plant, and the nature of the fungus, bacterium, or insect to be killed. One part of any of the mixtures emulsified in 50 to 150 parts of water is usually satisfactory.

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[4] With many combinations, such as the mixture of proper quantities of carbon tetrachlorid, liquor cresolis compositus, and water, very syrupy liquids are obtained.

Mr. Bruce Drummond, of the Office of Crop Physiology and Breeding Investigations, Bureau of Plant Industry, and inspector for the Federal Horticultural Board, has found that the following simple modification of the standard formula has proved to be very efficacious in eradicating the two most dangerous insect pests infesting the date palm, *Phoenicococcus Marlatti* and *Parlatoria Blanchardi,* at the Government Date Garden at Indio, Cal.:[5]

Cresylic soap liquor	1 part
Kerosene (or distillate)	4 parts
Water	250 parts

In case the water with which these solutions are to be prepared and diluted for spraying contains in solution large quantities of natural mineral salts, their salting-out effect upon the emulsions may be partly overcome by the addition of small quantities of sodium carbonate. A quantity sufficient to give the water a faint alkaline reaction is usually adequate for this purpose.

Liquor cresolis compositus may be purchased at any pharmacy and may be used to make any quantity of emulsion, however small, that is needed. When used on a large scale it will be found more economical to make up the liquor cresolis compositus rather than to buy it ready-made from the pharmacy. It is possible to manufacture the cresylic liquor still more cheaply by using an equivalent quantity of sodium hydrate instead of the potassium hydrate required by the usual formula. This does not appreciably diminish its solvent, emulsifying, and disinfecting powers.

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[5] Mr. Drummond reports that the addition of flour paste to the spray caused it to adhere to the tissue much better. This spray was very effective with air-pressure at 140, using the nozzle wide open. For disinfecting date offshoots after the leaves have been trimmed away and for spraying the trunks and enveloping leaf sheaths of old date palms in order to kill *Phoenicococcus Marlatti,* Mr. Drummond adds 0.5 parts of commercial formalin to the formula and thereby secures increased penetration.

EXTRACTION OF NITRATES FROM SOIL.[1]

R. S. POTTER AND R. S. SNYDER,

IOWA AGRICULTURAL EXPERIMENT STATION, AMES, IOWA.

Allen and Bonazzi[2] present data which seem to throw doubt upon the accuracy of any procedure for the determination of nitrates in soils which involves shaking or stirring the soil with a known amount of water, filtering and then taking an aliquot of the filtrate for analysis. In other words, it appears that by such a procedure the nitrates are incompletely extracted by water. The method by which the data were obtained which lead them to that conclusion, to quote the authors, is as follows:

> All extractions were made 1 : 5 on 100-gram portions of soil. From these mixtures of 500 c. c. of water and 100 grams of soil, 400 c. c. of clear solution were removed and replaced by an equal amount of distilled water. Since in the first extraction 100 c. c. of water is left in contact with the soil, the nitric nitrogen obtained in the second extraction should be, if complete extraction were effected, one-fifth of that obtained by the first extraction. Expressing the nitric nitrogen obtained by the first extraction as A, and that by the second as B, then in case of complete solution $B - A/5 = 0$, and $A + [B - (A/5)] = A$. In a large number of determinations, however, of which the following are typical, $A + [B - (A/5)]$ is greater than A.

Data from ten determinations are then given, which will not be repeated here. It is sufficient to say that instead of finding A equal to $A + [B - (A/5)]$ it was found that A was only equal to from 65.9 to 80.7 percent of $A + [B - (A/5)]$. The phenolsulfonic acid method was used.

In a recent publication[3] from this laboratory, it was shown that when nitrate was added to soil at the rate of three parts per million of soil, from 93 to 97 percent were recovered by shaking the soil with water, filtering, and determining the nitrates in an aliquot of the filtrate. Calcium carbonate was the flocculating agent and the phenolsulfonic acid method of analysis was used.

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[1] Contribution from the Laboratory of Soil Chemistry, Iowa Agricultural Experiment Station. Received for publication October 28, 1915.

[2] Allen, E. R., and Bonazzi, A., On Nitrification, Ohio Agr. Expt. Sta. Tech. Bul. 7. April, 1915.

[3] Potter, R. S., and Snyder, R. S., The Determination of Nitrates in Soil, Jour. Ind. Eng. Chem., 7: 863-864. 1915.

It is known that this colorimetric method is unreliable for the higher amounts of nitric nitrogen, giving results lower than the theoretical. In view of our recovery of practically all of the three parts per million of the nitric nitrogen and the unreliability of the phenolsulfonic acid method, it was thought that possibly the extraction was actually more complete than found by Allen and Bonazzi. To throw light on this question, the following experiment was planned. Varying amounts of nitric nitrogen as potassium nitrate were added to three soils, which were then shaken with water for half an hour,—two parts of water to one of soil,—using calcium carbonate as the flocculant. One-hundred-cubic-centimeter portions of the filtrate were analyzed, duplicates being run in every case.

The aluminum reduction method as used in this laboratory[4] was employed. Soil *A*, from the Wisconsin drift area, is a Miami silt loam. Soil *B*, from the same area, is a Carrington loam, and Soil *C* is a Mississippi loess soil. The results given in Table I are expressed as parts of nitric nitrogen per million of soil.

TABLE I.—*Data on recovery of nitric nitrogen from the soil by the aluminum reduction method.*

Soil.	Nitric nitrogen.			
	Added.	Found.	Recovered.	Recovered.
	p.p.m.	*p.p.m.*	*p.p.m.*	*Percent.*
A	None	20.30		
	15.95	36.40	16.10	101.0
	31.90	52.50	32.20	100.8
	50.00	70.00	49.70	99.4
	100.00	117.00	96.70	96.7
	150.00	168.20	97.90	97.9
B	None	21.30		
	15.95	37.30	16.00	100.3
	31.90	53.50	32.20	100.8
	50.00	72.85	51.55	103.1
	100.00	122.75	101.45	101.4
	150.00	172.90	151.60	101.1
C	None	19.60		
	15.95	35.60	16.00	100.3
	31.90	51.60	32.00	100.3
	50.00	70.60	51.00	102.0
	100.00	120.75	101.15	101.1
	150.00	170.90	151.30	100.9

From the data given in the table, it is seen that in all cases the recovery is practically complete.

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[4] Potter, R. S., and Snyder, R. S., *loc. cit.*

AGRONOMIC AFFAIRS.

THE JOURNAL FOR 1916.

The plans for the current year involve some changes in the JOURNAL which it is believed are in the nature of improvements. In the first place, the size of the bimonthly issues has been increased, at least temporarily, from 48 to 64 pages. When the publication of the JOURNAL was begun three years ago, the volume consisted of four numbers of 64 pages each, a total of 256 pages during the year. In 1914, the change was made from the quarterly to the bimonthly form, with about 48 pages in each issue and a total of 294 pages in the volume. During the year just closed, the 48-page bimonthly issue was continued, with the exception that the two numbers which completed the volume were of 64 pages each, making a total of 320 pages. This increase in size was justified both by the financial condition of the Society and by the supply of material available for publication.

The rapid increase in the membership of the Society and the resulting increase in income justifies the announcement at this time of the publication of a 64-page JOURNAL bimonthly so long as the supply of material is sufficient. This means a volume of 384 pages, one full 64-page number more than was published in 1915 and two such numbers more than were published in 1913. Whether or not these are issued as planned depends entirely on the supply of suitable copy. Along with the increase in size of the JOURNAL, it is hoped to still further increase the regularity of issue. Because of the more abundant supply of copy during the past year there was an improvement in this regard over former volumes, but there is still much to be desired. So far as possible, the issues will appear about the first of each alternate month, beginning with February 1.

A feature of general interest during the year is the series of articles on agronomic terminology which is projected. These will be contributed by Mr. Carleton R. Ball, for several years the chairman of the Society's committee on this subject, and by others who are interested in making more exact and accurate the terms which are in more or less common use among agronomists. An introductory article to this series, by Messrs. Ball and Piper, is included in this issue. With a comparatively new and rapidly developing science like agronomy, there is much need for a glossary of terms such as it is planned to formulate. It is hoped that the articles published during the year will be made the subject of comment by members of the Society, for it is only through a full and free discussion that we can hope to reach any agreement on the use and meaning of agronomic terms.

When publication in magazine form was begun, the income of the Society did not justify the giving of free reprints to authors. That time is happily now past, and by a recent vote of the executive committee the JOURNAL will, beginning with this issue, supply 50 free reprints of each article which is published therein. This is a courtesy which the editor believes will be appreciated by those who contribute to these pages.

There is need for manuscripts on every phase of agronomic endeavor—experimentation, demonstration, instruction, and research. Papers of any length from brief notes to 30 printed pages can be used, but the preference will be given to short, pithy papers giving the results of original research, outlining methods of instruction, or presenting other information of general interest to agronomic workers. See the inside front cover page of this issue for further information regarding the preparation of papers. Items of interest regarding persons or institutions engaged in agronomic work are specially welcome. The secretaries of other organizations are urged to send notices of the place and date of meeting of their respective societies for publication under the heading of "Coming Events." Let us all work together to make the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY bigger and better in 1916 than in any previous year of its history!

LOCAL SECTIONS OF THE SOCIETY.

The organization of two new local sections, as recorded elsewhere in this issue, serves to call attention to this feature of the American Society of Agronomy and to suggest that similar action might prove of value in numerous other institutions. There are now six local sections of the Society, the locations of these, in the order of their organization, being as follows: Cornell University; Kansas State Agricultural College; Washington, D. C.; Iowa State College; Minnesota College of Agriculture; and Ohio State University. The following article in the Constitution of the Society provides for the formation of local sections:

LOCAL SECTIONS.

Article V. Any three members may, with the approval of the executive committee, organize a local section of ten or more persons who, if not already members of the Society, may become active or associate members on application and payment of regular dues for such membership. Local sections may make their own rules for membership, provided that for each member who does not become an active or associate member of the Society a fee of fifty cents, which shall make such person a local member of the Society and entitled to purchase its *Proceedings* for a sum not to exceed the difference between a local member's fee and the annual dues for active membership, but shall not entitle him to a vote in the Society. Any local section may be dissolved by a majority vote of members present at any regular meeting of the Society.

In addition to the 6 in which local sections have already been organized, there are 28 institutions which have the requisite 3 members to begin the organization of a local section. The additional members to make the 10 necessary for the section may or may not take full membership in the Society, as they desire. Of the 28 institutions named below where the Society has 3 or more members, 17 have 5 or more members and 5 already have the requisite 10 members for the section. The 28 institutions are:

Arkansas College and Station,
California University and Station,
Georgia College of Agriculture,
Illinois University and Station,
Indiana (Purdue) Univ. and Station,
Kentucky University and Station,
Macdonald College,
Maryland College and Station,
Massachusetts College and Station,
Michigan College and Station,
Missouri University and Station,
Nebraska University and Station,
New Hampshire College and Station,
New Jersey College and Station,
North Carolina College and Station,
North Dakota College and Station,
Ohio Station,
Oregon College and Station,
Pennsylvania College and Station,
Rhode Island College and Station,
South Dakota College and Station,
Tennessee University and Station,
Texas College and Station,
Utah College and Station,
Virginia College and Station,
Washington College and Station,
West Virginia College and Station,
Wisconsin University and Station.

The institutions where there are 10 or more members and where local sections have not been organized, with the number of members at each, are Illinois University and Station, 19; Indiana (Purdue) University and Station, 16; Georgia College of Agriculture, 11; California University and Station, 10; and Texas College and Station, 10. In addition, there are 9 members each at the Missouri University and Station, North Dakota College and Station, and Wisconsin University and Station, 8 at the Oregon College and Station, and 7 each at the North Carolina College and Station, Ohio Station, Pennsylvania College and Station, and Utah College and Station.

The present writer can not do better than to present again the statement regarding the benefits to be derived from the organization of local sections of the Society which appeared in the JOURNAL for July–September, 1913. At that time Mr. C. R. Ball wrote:

> The benefits resulting from a local organization of the agronomic workers in an institution scarcely need argument For the purpose of presenting and discussing methods and results of research and instruction it is invaluable. It also serves to develop mutually helpful relations between faculty, graduate students, and advanced undergraduates, giving the latter an opportunity to develop and prove their abilities under the inspiration and criticism of the former. Then, too, it serves as a nucleus to attract and present lectures on fitting topics by visiting scientists. . . .
>
> An additional advantage will accrue to . . . local sections of the American Society of Agronomy. They will have a sense of fellowship and unity of purpose with the national organization and with similar sections elsewhere, as well as the added prestige of membership in the Society. The JOURNAL will furnish a medium of communication as well as matter for review at meetings.

The members of the Society in the institutions named above are earnestly requested to consider the desirability of organizing local sections of the Society. If additional information or suggestions are desired, they will be gladly furnished on request.

DOCTORATES CONFERRED BY AMERICAN UNIVERSITIES.

In a recent number, *Science*[1] publishes the names of those on whom the doctorate degree was conferred in the natural and exact sciences by American universities in 1915, and presents some interesting data on doctorate degrees conferred during the past 18 years. The degree of doctor of philosophy or of science was conferred on 556 persons during the last college year, an increase of 10 percent over the previous year and double the average number for the 10 years ending in 1907. The largest number of doctorate degrees was granted by Columbia, with Chicago, Harvard, Yale, Pennsylvania, Cornell, and Johns Hopkins following in the order named. In total number of such degrees granted during the past 18 years the order is the same, except that Johns Hopkins ranks ahead of Pennsylvania and Cornell.

Of the 309 doctorates in the natural and exact sciences, the greatest number, 85, was in chemistry, with botany, zoology, physics, and geology following in the order named. Nine doctorate degrees were conferred in agriculture, 5 by Cornell and 4 by Illinois. Following will be found the titles of theses more or less closely related to agronomy, with the names of those on whom the degrees were conferred and of the universities granting them.

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[1] Science, n. s., vol. 42, no. 1086, pp. 555–565. Oct. 22, 1915.

CORNELL UNIVERSITY.

Millard Alschuler Klein: "Studies in the Drying of Soils."

Carl Edwin Ladd: "Cost Accounts on Some New York Farms for 1912–13."

Leonard Amby Maynard: "The Fixation of Nitrogen by Sweet Clover."

James Kemp Plummer: "The Effect of Oxygen and Carbon Dioxid on Nitrification and Ammonification in Soils."

Arthur Lee Thompson: "The Cost of Producing Milk on 174 Farms in Delaware County, N. Y."

James Kennith Wilson: "Physiological Studies of *Bacillus radicola* of Soy Bean (*Soja max* Piper) and of Factors Influencing Nodule Production."

UNIVERSITY OF ILLINOIS.

Demetrius Ion Andronescu: "The Physiology of the Pollen of *Zea Mays* with Special Regard to Vitality."

William Leonidas Burlison: "Availability of Mineral Phosphates for Plant Nutrition."

Wallace Macfarlane: "Solubility of Lime Carbonates in Relation to Their Endurance in Soils."

Frank Archibald Wyatt: "The Influence of Calcium and Magnesium Compounds on Plant Growth."

JOHNS HOPKINS UNIVERSITY.

Forman Taylor McLean: "A Preliminary Study of Climatic Conditions as Related to the Growth of Soy Bean Seedlings."

John Wesley Shive: "A Study of Physiological Balance in Nutrient Media Resulting in a Simplified Culture Solution for Plants."

UNIVERSITY OF CHICAGO.

Joseph Stuart Caldwell: "A Study of the Effects of Certain Antagonistic Solutions upon the Growth of *Zea Mays*."

George Burton Rigg: "Decay and Soil Toxins."

HARVARD UNIVERSITY.

Guilford Bevil Reed: "Studies in Plant Oxidases."

UNIVERSITY OF CALIFORNIA.

Richard Morris Holman: "The Orientation of Terrestrial Roots with Particular Reference to the Medium in Which They Are Grown."

UNIVERSITY OF MINNESOTA.

Morris Joslin Blish: "The Chemical Composition of Wheat Proteins and Their Relation to Baking 'Strength' in Flour."

UNIVERSITY OF NEBRASKA.

George Borrowman, Jr.: "The Clays of Nebraska."

UNIVERSITY OF WISCONSIN.

Howard Edward Pulling: "The Movement of Water in Aerated Soils."

WASHINGTON UNIVERSITY.

Melvin Clarence Merrill: "The Electrolytic Determination of Exosmosis from the Roots of Plants Subjected to the Action of Various Agents."

YALE UNIVERSITY.

Isaac Faust Harris: "Chemical and Physiological Studies of the Castor Bean and Soy Bean."

MEMBERSHIP CHANGES.

The membership reported at the end of the year 1915 was 471. Forty-five new members have already been added for 1916, making the total membership at this date 516. The names and addresses of the new members, together with the changes which have been reported in the addresses of members published in the previous issue, are as follows:

NEW MEMBERS.

ABELL, M. F., Farm Crops Dept., College of Agr., Ithaca, N. Y.
BACHTELL, M. A., Townshend Hall, Ohio State Univ., Columbus, Ohio.
BEESON, M. A., Dept. Agron. Okla. Agr. and Mech. College, Stillwater, Okla.
BIGGAR, H. HOWARD, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
BOARDMAN, W. C., Experiment Station, Wooster, Ohio.
BUSHEY, A. L., 210 Waldron St., La Fayette, Ind.
CATES, HENRY R., Bur. Plant Indus, U. S. Dept. Agr., Washington, D. C.
CORSON, GEORGE F., Dept. Farm Crops, Iowa State College, Ames, Iowa.
COWGILL, H. B., Insular Agr. Sta., Rio Piedras, Porto Rico.
CURTIS, ERNEST W., Truckee-Carson Field Station, Fallon, Nev.
DORYLAND, C. J. T., Expt. Station, Agricultural College, N. Dak.
DU BUISSON, J. P., 301 Bryant Avenue, Ithaca, N. Y.
DULEY, F. L., 705 Hitt Street, Columbia, Mo.
DUNNEWALD, T. J., Office of Soil Survey, Madison, Wis.
EMERSON, PAUL, Soils Dept., Iowa State College, Ames, Iowa.
FISHER, FOREST A., Agr. Experiment Station, Urbana, Ill.
GOODALL, S. E., Owensmouth, Cal.
HARRISON, T. J., Agricultural College, Winnipeg, Manitoba, Canada.
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NOTES AND NEWS.

P. B. Barker, formerly professor of instructional agronomy and associate agronomist in the Nebraska university and station, became associate professor of field crops in the extension service of the University of Missouri on September 1. Professor Barker is joint author with Horace J. Young, assistant professor of agronomy in the University of Nebraska, of "A Manual of Soil Physics," recently published by Ginn & Co.

E. O. Holland, until recently superintendent of schools of the city of Louisville, Ky., has been elected president of the Washington State College to succeed E. A. Bryan, resigned.

F. J. Schneiderhan of the Minnesota College of Agriculture has been appointed a scientific assistant in the office of cereal investigations of the Federal Bureau of Plant Industry.

Alfred Vivian, professor of chemistry at Ohio State University since 1905, has been appointed dean of the college of agriculture in the same institution. Dean Vivian is a graduate of the University of Wisconsin, where he was connected with the agricultural chemistry division of the college and station for eight years. For the past thirteen years he has been engaged in work in agricultural chemistry in the college of which he has recently been made dean.

Science reports that Mrs. Russell Sage has given Syracuse University a fund with which to build a college of agriculture as a memorial to her father, Joseph Slocum. Construction of the building, which will cost several hundred thousand dollars, will be started early next spring. The gift of $500,000 to Delaware College by an unnamed donor is also reported. This amount will be used for the construction of a science hall for the agricultural and chemical departments, the remodeling of a dormitory building, and for maintenance.

The Association of Official Agricultural Chemists held its annual meeting at the Raleigh Hotel, Washington, D. C., on November 17. R. N. Brackett of Clemson College was elected president; J. K. Haywood of the U. S. Department of Agriculture, vice president; C. L. Alsberg of the U. S. Department of Agriculture, secretary-treasurer; and W. J. Jones, jr., of Purdue University and E. B. Holland of Massachusetts Agricultural College, additional members of the executive committee.

The fifth annual meeting of the American Association of Milling and Baking Technology was also held in Washington, D. C., on November 17. Reports on milling experiments were made by Miss Leila Dunton; on baking, by C. H. Bailey; on analytical methods, by B. R. Jacobs; and on baking-powder experiments, by T. J. Bryan. The officers for the ensuing year are: R. W. Thatcher of the Minnesota College of Agriculture, president; B. R. Jacobs of the U. S. Department of Agriculture, vice president; and J. A. LeClerc of the U. S. Department of Agriculture, secretary-treasurer. The referees and associate referees for the year are: Milling, Miss Leila Dunton and C. J. Patterson; baking, C. H. Bailey and Miss Hannah L. Wessling; analytical methods, R. Harcourt and F. W. Emmons; and baking-powder experiments, T. J. Bryan and J. R. Chittick.

Prizes for Work in Soil Physics.

The following announcement of interest to agronomists appeared in the November, 1915, issue of *The Plant World:*

> At the suggestion of one of our subscribers, and with the encouragement of several other persons, The Plant World announces the offering of two prizes for the best papers embodying original work in soil physics. The first prize will be $50 and the second $25, with the reservation of the right to withhold both prizes if no worthy papers are submitted, or to combine the prizes for the rewarding of a paper of exceptional merit. The conditions governing the award will be similar to those employed in connection with the prizes for papers

on the water relations of plants, which were offered in April, 1915. The names of the judges who will appraise the submitted papers will be announced in a later issue. The contesting contributions should be in the hands of the editor of The Plant World by December 1, 1916, and the announcement of the award will be made not later than March 1, 1917. The early announcement of this contest is made in the hope that an entire year will afford time for a vigorous competition.

Local Sections.

At the annual meeting of the Iowa State College local section of the American Society of Agronomy, Paul Emerson was elected president and F. S. Wilkins, secretary.

A local section of the Society was organized at the College of Agriculture, University of Minnesota, on October 26, 1915, with 10 members. The section will meet every two weeks during the college year to discuss matters of agronomic interest. C. P. Bull, associate professor of agronomy, was elected president and C. H. Bailey, assistant professor of agricultural chemistry, secretary.

In November a local section was organized at Ohio State University with 18 members. Meetings are held in the evening of the second Tuesday of each month from October to May, inclusive. The officers for the current year are Thos. G. Phillips, president; F. W. Stemple, vice-president; and A. F. Head, secretary-treasurer.

The ninth meeting of the Washington, D. C., local section was held at the Cosmos Club on November 23, 1915. H. S. Coe discussed "Recent Developments in the Culture of Sweet Clover," giving a brief resume of the present-day uses of this crop and directions for its culture. He especially recommended sweet clover as a green-manure crop on land too poor to grow red clover or other legumes, stating that no other plant puts run-down farms into good condition so quickly. L. H. Dewey gave an illustrated talk on "Binder Twine Fibers," in which he briefly sketched the development of harvesting machinery and of the use of binder twine. The value of binder twine used in the United States in 1915 was stated to be about $25,000,000. Interesting information was presented regarding the principal sources of binder-twine fiber, henequen, sisal, and abaca, with lantern slides showing the culture and preparation of each. The following officers were elected for the ensuing year: President, F. D. Farrell; vice president, F. C. Miles; secretary-treasurer, H. L. Westover; and additional members of the executive committee, T. R. Stanton and Fred D. Richey.

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THE USE OF CHECKS AND REPEATED PLANTINGS IN VARIETAL TESTS.[1]

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Although methods of testing varieties of farm crops have undergone critical analysis in recent years and some efforts have been made towards the adoption of a uniform system, we still find a great diversity of practice. Certain agronomists, thoroughly imbued with the magnitude of seasonal variations, dispense with field controls and devote their attention to climatic factors, omitting from their summaries the results of abnormal years, while others endeavor to control the inequalities of the soil by means of frequent checks and repeated plantings, but practically disregard seasonal influences. Obviously neither of these methods is ideal. The failure to take the irregularities of both the season and the soil into consideration extends the experiment over a long period of years. A ten-year period, which is often advocated, has a number of disadvantages. It makes the farmers wait too long for results and offers to individuals and companies no encouragement for the production of new varieties because so much time is required to test their merits and it is uncertain whether another equal period would give similar results. An approximately perfect method covering both seasonal and field control should give greater efficiency and a shorter test than is ordinarily afforded by current methods.

From a study of the controls used in sugar-beet breeding exper-

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[2] The writer wishes to acknowledge his indebtedness to Dr. H. L. Reitz for many helpful suggestions.

iments, a few facts have been deduced regarding the relative efficiency of several different frequencies of checks and replications which appear significant. These studies lead us to believe that, in spite of the steady advance made in this field, especially within the last decade, our chief obstacles still lie in our methods. What is true of varietal testing in this respect applies with still greater force to operations in breeding where, on account of a shortage of seed, it is often difficult to make a sufficient number of replications.

Source and Character of the Material Used.

The results presented in this paper are based upon the control rows and progeny rows from selected plants used in our experiments in sugar-beet breeding in 1912. All check or control rows were sown with the variety Kleinwanzleben's Original. The seed was taken from a sealed bag in order to increase the probability of its all being grown in one locality under similar environmental conditions. It was thoroughly mixed and each alternate row was then sown with this seed. The intervening rows were each sown with the seed of a single plant, i. e., they were progeny rows. The distance between a progeny row and its check rows was 16 inches on each side; from check row to check row was 32 inches. At the time of harvest all rows were cut to a length of 50 feet.

Chemical Control.

The chemical analyses were made by practical sugar chemists under the direction of W. B. Clark, supervising chemist of the Office of Sugar-Plant Investigations. A Keil and Dolle beet-boring machine was used for taking samples. All beets were bored diagonally at a uniform angle beginning just below the crown and extending through the main part of the root. The sugar was extracted by means of cold water digestion and the extraction checked frequently with hot water digestion.

The quantity of sugar for each beet was determined by multiplying its total weight by its percentage of sugar. This gives a slightly higher quantity of sugar than is actually present, as the crown and the small end of the beet contain a lower percentage of sugar than the intermediate part. As the calculations were made on all beets alike the results are comparable, however.

The quantity of sugar for the row was determined by adding the calculated quantities of sugar for its individual beets; the percentage of sugar, by dividing the total quantity of sugar by the total weight of beets in the row.

CONDITIONS UNDER WHICH THE MATERIAL WAS GROWN.

The soil was a fertile clay loam with a clay subsoil. The surface was nearly level, but the drainage was good. The field had been liberally coated in previous years with barnyard manure, but had since grown several crops of tobacco. No commercial fertilizer or barnyard manure was applied in 1912.

OBJECTS OF STUDY.

Three objects were attempted: (1) To determine the optimum frequency of checks, (2) to ascertain whether the best frequency of checks studied is efficient enough for satisfactory comparisons, and (3) to measure the comparative effect of repeated plantings upon the experimental error.

COMPARISON OF CHECKS OF DIFFERENT FREQUENCIES.

The use of check rows (or plats) is generally considered necessary to make an accurate comparison of varieties, but the relative merits of the different frequencies of checks employed for this purpose are not well known. The closer a check row lies to the progeny row the more satisfactory it would appear to be theoretically. There is some experimental evidence which seems to support this hypothesis, but, owing to the expense of using so many check rows, in actual practice every third, every fifth, or even every tenth row frequently is used for this purpose. In view of these supposable sacrifices in efficiency on account of economy it seems desirable to determine the relative merits of several different frequencies of check rows.

The material employed for the study of different frequencies of checks was the control rows used in our sugar-beet breeding experiments in the year 1912. They were sown alternately with progeny rows, but the latter were not used in making computations for the present comparison. The arrangement of rows and order of numbering are shown in figure 1.

The relative efficiency of several different frequencies of check rows lying at distances of 32, 64, 96, 128, and 160 inches from the progeny row was determined by using each of 300 rows consecutively as a standard of comparison and finding how much similar rows at these respective distances from the standard deviated from it, on the average, in yield and in percentage of sugar. The frequency, or distance, which showed the smallest average deviation from the standards was assumed to be the most efficient, as all these rows were planted with a single variety of relatively homogeneous seed. Hence the deviations are due to irregularities in the field conditions, and the frequency which reduces this deviation to the minimum will be the most helpful in distinguishing real differences between varieties.

The foregoing plan for determining the relative efficiency of different frequencies of checks was put into operation by using in succession each check row of the experimental field for 1912 (see fig. 1), with the exception of a few at the beginning and end of the series, as a standard of comparison and comparing five successive pairs of neighboring rows (check rows) with it in percentage of sugar and in total yield of sugar. The pair of rows lying nearest to the standard (32 inches from it on each side) was termed the first pair of rows from the standard, and the pairs lying at distances of 64, 96, 128, and 160 inches on each side the second, third, fourth, and fifth pairs respectively from the standard. Table 1 shows the rows used as the first four standards and the grouping for their corresponding five pairs.

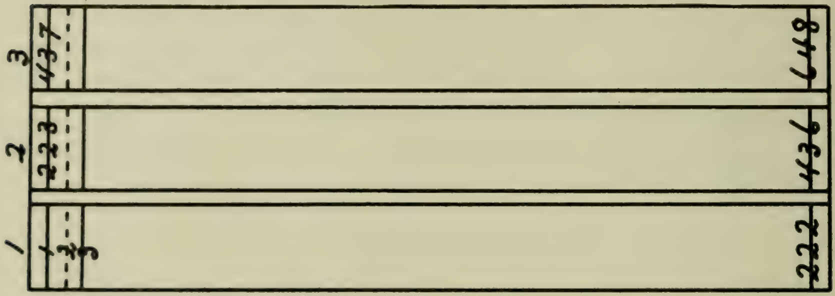

FIG. 1. Diagram illustrating the arrangement of rows and strips in the experimental field in 1912. Solid lines represent check rows; dotted lines represent progeny rows.

TABLE 1.—*Plan of using check rows as standards and as successive pairs of rows from each standard.*

Standards.		Row numbers of successive pairs of rows from standards.				
Sequence.	Row No.	First pair 32 inches from standard.	Second pair 64 inches from standard.	Third pair 96 inches from standard.	Fourth pair 128 inches from standard.	Fifth pair 160 inches from standard.
1	11	9, 13	7, 15	5, 17	3, 19	1, 21
2	13	11, 15	9, 17	7, 19	5, 21	3, 23
3	15	13, 17	11, 19	9, 21	7, 23	5, 25
4	17	15, 19	13, 21	11, 23	9, 25	7, 27

The grouping[3] for only four standards and their five successive pairs of rows is shown in Table 1, but the same system was continued throughout the series, i. e., about 300 standards were used, each with its accompanying five pairs of rows.

The difference between each standard row and the mean of its nearest pair of rows was determined without regard to the plus or minus sign, and recorded as a deviation from the standard. From the total number of deviations thus separately determined the mean deviation was calculated for the first pair. To illustrate, let us compute a single deviation. The sugar content for row 11, which is used as the first standard, is 14.5 percent, while for rows 9 and 13 (its first or nearest pair of rows) it is 13.8 and 14.1 percent respectively. Completing the computation, we find that $14.5 - \frac{13.8 + 14.1}{2}$ or 0.6 represents the deviation of this pair of rows from its standard. The deviation of every other first pair of rows from its standard was computed in a similar way. From the total number of deviations thus obtained, the arithmetical mean was calculated, which represents the mean deviation of the first pairs of rows from their standards. The mean deviation from the standards was likewise determined for the second, third, fourth, and fifth pairs of rows respectively.

As there are a number of practical agronomists who prefer to dispense with check rows and use the mean of all rows in the test as a standard of comparison, the deviation was also found between each standard row and the mean of all the check rows used in the breeding experiments (see fig. 1). While the mean of all rows represents no particular frequency of checks and in this respect is not comparable with the other material, nevertheless it shows the relative merits of this practice as compared with the frequent use of checks.

The frequency distributions prepared for the five pairs of rows and for the mean of all rows, showing deviations in percentage of sugar from the standards and also the mean deviation and standard deviation of percentage deviation for each group, are summarized in Table 2.

The first pairs of rows vary the least from the standards as shown by their mean deviation, 0.49 percent, as compared with 0.58, 0.60, and 0.62, and 0.60 percent respectively, and hence are the most efficient controls. The second, third, fourth, and fifth pairs are of about equal value, as their variation from one another does not exceed three times the probable error of the difference,[4] while the mean of all the rows shows the greatest deviation from the standards and is certainly significant.

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[3] The use of each consecutive row as a standard of comparison causes every row to appear in several different combinations. This has no advantage over the employment of a system which uses each row only once except that it affords a larger number of combinations with a limited number of rows.

The deviations in yield are likewise summarized in Table 3.

TABLE 2.—*Frequency distributions showing deviations in percentage of sugar from standards.*

Deviations in percentage of sugar.	Rows.					Mean of all rows.
	First pair.[a]	Second pair.	Third pair.	Fourth pair.	Fifth pair.	
Percent.						
0 –0.1[b]	70	58	57	51	54	32
0.2–0.3	81	71	60	64	80	35
0.4–0.5	45	58	52	59	41	49
0.6–0.7	40	32	44	36	33	43
0.8–0.9	26	19	27	25	27	37
1.0–1.1	15	18	19	23	23	28
1.2–1.3	9	16	9	18	13	20
1.4–1.5	4	12	12	7	12	26
1.6–1.7	3	7	6	3	7	10
1.8–1.9	1	5	11	5	6	6
2.0–2.1	6	2	4	4	1	2
2.2–2.3	2	2	—	3	—	3
2.4–2.5	—	1	1	—	1	4
2.6–2.7	—	1	—	1	2	2
2.8–2.9	—	—	—	1	2	2
3.0–3.1	—	—	—	2	—	2
3.2–3.3	—	—	—	—	—	1
3.4–3.5	—	—	—	—	—	—
Total	302	302	302	302	302	302

	Mean deviation.	Standard deviation.
First pair	0.49 ± .018	0.46 ± .013
Second pair	.58 ± .020	.52 ± .014
Third pair	.60 ± .020	.51 ± .014
Fourth pair	.62 ± .020	.55 ± .015
Fifth pair	.60 ± .020	.54 ± .015
All rows	.84 ± .024	.61 ± .017

[a] The mean of each pair of rows was used to determine their deviation from the standard.

[b] The determinations were made only to the first decimal place, but in reality class 0 to 0.1 contains values ranging from 0 to 0.15, while class 0.2 to 0.3 contains values varying from 0.15 to 0.35, class 0.4 to 0.5 from 0.35 to 0.55, etc. Hence class 0 to 0.1 is 0.05 narrower than the remaining classes.

[4] The probable error of a difference is found by extracting the square root of the sum of the squares of the probable errors of the two numbers.

TABLE 3.—*Frequency distributions showing deviations in grams of sugar from standards.*

Deviations in grams of sugar.	Rows.					Mean of all rows.
	First pair.[a]	Second pair.	Third pair.	Fourth pair.	Fifth pair.	
Grams						
0– 99[b]	54	44	57	41	41	27
100– 199	55	50	39	47	43	22
200– 299	45	40	38	38	36	24
300– 399	39	33	33	33	46	27
400– 499	31	32	22	35	37	21
500– 599	24	27	30	24	24	29
600– 699	16	16	18	23	14	24
700– 799	10	11	11	17	13	23
800– 899	12	5	13	11	13	16
900– 999	6	10	12	6	6	18
1,000–1,099	2	9	7	9	5	12
1,100–1,199	—	4	3	8	9	7
1,200–1,299	3	3	5	3	6	9
1,300–1,399	1	8	2	1	2	9
1,400–1,499	1	3	5	1	1	11
1,500–1,599	1	3	1	—	1	2
1,600–1,699	—	2	4	—	1	13
1,700–1,799	—	—	—	2	1	2
1,800–1,899	—	—	1	2	—	2
1,900–1,999	—	1	—	—	1	1
2,000–2,099	—	—	—	—	—	—
2,100–2,199	—	—	—	—	—	—
2,200–2,299	—	—	—	—	—	[c]1
2,300–2,399	—	—	—	—	**1**	1
2,400–2,499	—	—	—	**1**	**1**	—
2,500–2,599	**1**	—	—	—	—	1
2,600–2,699	—	**1**	—	—	—	—
2,700–2,799	[d]**1**	—	—	—	—	—
2,800–2,899	—	—	**1**	—	—	—
Total	(302) 300	(302) 301	(302) 301	(302) 301	(302) 300	(302) 299

	Mean deviation.	Standard deviation.
First pair	356.17 ± 11.02	283.00 ± 7.79
Second pair	450.50 ± 15.02	386.35 ± 10.62
Third pair	449.83 ± 14.92	383.67 ± 10.55
Fourth pair	445.51 ± 13.59	349.54 ± 9.61
Fifth pair	443.50 ± 13.70	351.84 ± 9.69
All rows	694.53 ± 19.15	493.43 ± 13.54
	677.59 ± 18.17	465.69 ± 12.85

[a] One half the yield of each pair of rows was used to determine the deviation from the standard.

[b] Class "0–99" in Tables 3, 5, and 6 is 0.5 narrower than the remaining classes, as the class ranges are in reality 0 to 99.5; 99.5 to 199.5; 199.5 to 299.5, etc., respectively, although the determinations were made only to the nearest unit.

[c] As this frequency distribution is somewhat irregular, the constants were calculated for both 302 and 299 variates.

[d] The figures in boldface type were not used in calculating the constants.

The results shown in Table 3 correspond closely to those shown in Table 2. The first pairs of rows have the smallest mean deviation from the standards; the remaining pairs vary about equally instead of showing a graduated value corresponding to their proximity to the standards, while the mean of all rows shows the largest deviation.

Efficiency of Every Alternate Row as a Check.

In our conception of a theoretically ideal frequency, the check and trial plants should stand as close together as possible without interfering with normal growth or giving either an advantage on account of its superior competitive powers. This would provide each class of plants (i. e., check and trial plants) with approximately the same conditions of growth. If under these circumstances their hereditary powers were similar except for an occasional fluctuation, the mean yields should be similar when compared with due regard to probable errors. The farther the checks are removed, within certain limits, the greater the probability of their occupying positions either more favorable or less favorable for growth, which would affect their mean yield accordingly. If there were no difference in the inherent yielding power of the breeding and the control materials (i. e., progeny rows and check rows), a difference in their mean yields in field tests would signify a deficiency in the number of checks employed.

We shall now apply the foregoing test to the system of checks previously outlined and used in our breeding experiments (fig. 1) where every alternate row was employed as a control. The mean yields of progeny rows and check rows in 1912 and 1913, together with their frequency distributions, are presented in Table 4.

The mean yields of progeny rows and check rows for 1912 show a difference of 278.37 (± 46.76) grams, approximately six times the probable error, and 244.46 (± 30.34) grams, or over eight times the probable error, for 1913. These differences are significant and show that either too few checks were used or that we have erred in assuming a similarity in the inherent yielding power of the control and breeding materials. That their inherent yielding power is similar we have reason to believe from varietal tests made at Madison in 1912 and 1913 and elsewhere in previous years, in which Kleinwanzleben's Original and Morrison's Kleinwanzleben (commercial seed) were used. Hence we shall assume that the difference in the mean yields of Morrison's Kleinwanzleben and Kleinwanzleben's Original as exhibited in the breeding experiments was due in part at least to an insufficient number of checks. In other words, according to the results of this statistical treatment the use of every alternate row as a check does not seem to be a satisfactory means of comparing the relative merits of sugar-beet varieties.

TABLE 4.—*Comparative yield of sugar per row in 1912 and 1913, as shown by frequencies of yields of progeny and check rows in various weight classes.* (Weight classes designated by centers of classes of 121 grams range.)

RESULTS IN 1912.

Weight class.	Progeny rows.	Check rows.	Weight class.	Progeny rows.	Check rows.	Weight class.	Progeny rows.	Check rows.
Grams.			*Grams.*			*Grams.*		
2,413	1	–	3,744	8	3	5,075	5	14
2,534	2	–	3,865	8	4	5,196	4	5
2,655	2	1	3,978	12	5	5,317	4	5
2,776	–	–	4,107	11	6	5,438	2	1
2,897	1	2	4,228	20	10	5,559	–	3
3,018	3	3	4,349	8	11	5,680	–	2
3,139	2	1	4,470	6	10	5,801	–	–
3,260	4	3	4,591	19	20	5,922	–	3
3,381	2	3	4,712	16	14	6,043	1	2
3,502	5	3	4,833	11	24			
3,623	6	4	4,954	10	10	Total....	173	173

RESULTS IN 1913.

Weight class.	Progeny rows.	Check rows.	Weight class.	Progeny rows.	Check rows.	Weight class.	Progeny rows.	Check rows.
Grams.			*Grams.*			*Grams.*		
1,203	1	—	2,171	16	11	3,139	—	1
1,324	—	—	2,292	12	12	3,260	—	—
1,445	2	—	2,413	10	19	3,381	—	1
1,566	3	1	2,534	4	13	3,502	—	1
1,687	6	3	2,655	2	7	—	—	—
1,808	10	4	2,776	1	5			
1,929	15	9	2,897	—	1	Total....	98	98
2,050	16	10	3,018	—	—			

	Mean yield.	Standard deviation.	Coefficient of variability.
Progeny rows in 1912	4,276.26 ± 32.67	637.08 ± 23.10	14.90 ± 0.55
Check rows in 1912	4,554.63 ± 33.45	652.34 ± 23.65	14.32 ± 0.53
Difference in mean yields ...	278.37 ± 46.76		
Progeny rows in 1913	2,074.70 ± 19.64	288.18 ± 13.88	13.89 ± 0.83
Check rows in 1913	2,319.16 ± 23.13	339.40 ± 16.35	14.63 ± 0.86
Difference in mean yields ...	244.46 ± 30.34		

We may test the efficiency of the foregoing frequency of checks by means of another method, however, which enables us to eliminate the assumption of similarity in the inherent yielding power of the breeding and the control materials, i. e., progeny rows and check rows. If the check rows are as variable as the progeny rows it would be difficult if not impossible to distinguish the progeny rows of superior intrinsic value by the use of every alternate row as a check. That the progeny rows are as variable as the check rows is shown by the standard deviations and coefficients of variability of Table 4. We may arrive at approximately the same conclusion from a little different method. Since the standards and adjacent pairs of rows of Table 3 are check rows, we may determine the comparative variability of check and progeny rows by comparing the mean deviation of the adjacent pairs of rows from their standards with the mean deviation of the progeny rows from the checks. The deviations found between check rows and progeny rows are recorded in Table 5.

TABLE 5.—*Deviations in grams of sugar of progeny rows from check rows.*[a]

Weight class.	Distance from check rows.	
	16 inches	48 inches.
Grams.		
0– 99	21	34
100–199	25	21
200–299	25	14
300–399	21	23
400–499	20	19
500–599	20	13
600–699	18	11
700–799	6	5
800–899	5	8
900–999	3	5
1,000–1,099	5	5
1,100–1,199	1	6
1,200–1,299	1	5
1,300–1,399	1	3
1,400–1,499	–	1
1,500–1,599	1	2
1,600–1,699	1	–
1,700–1,799	1	1
Total	175	176

	Mean deviation.	Standard deviation.
16 inches from check rows	431.79 ± 16.28	319.42 ± 11.52
48 inches from check rows	472.80 ± 19.75	388.41 ± 13.96

[a] No data from rows having less than 80 percent stand were tabulated.

The mean deviations of the progeny rows from their check rows were 431.79 (± 16.28) and 472.80 (± 18.75) grams when the checks were respectively 16 and 48 inches distant. As the adjacent pairs of rows were separated 32 inches from the standards in the control material (Table 3, first pair of rows), we shall compare their mean deviation, 356.17 (± 11.02), with each of the foregoing constants. The differences are 75.62 (± 19.65) and 116.63 (± 22.39) grams or less than four times the probable error in the one case and only 27.07 grams in excess of it in the other. Hence it is by no means certain that the controls are significantly less variable than the progeny rows, which virtually destroys their value as a standard of comparison. From the results of this study it would appear that no number of control rows lying 16 inches or more from the progeny or variety row is sufficient to insure a satisfactory comparison between strains or varieties of sugar beets except when they are used in combination with replications of each strain or variety, which, as will be subsequently shown, greatly reduces the experimental error.

Effect of Repeated Plantings on the Experimental Error.

In all varietal tests of plants there is an experimental error arising from irregularities of the soil and other field conditions lying beyond the control of the operator. No matter how homogeneous the seed may be, the yield of rows or plats will vary considerably on account of these uncontrollable factors. This experimental error may be partly overcome by planting each variety several times and using its average as its representative value. However, the relative efficiency of different numbers of replications in reducing the experimental error and also the total reduction which can be obtained from a practical use of them are still matters which need careful study. An attempt is here made to throw some light on this problem for one crop grown under one set of conditions but a large number of such studies will be necessary to discover the most desirable system of replications for practical varietal testing in general.

The material employed to study the effect of replications upon the experimental error consisted of the check rows planted in our experimental field in 1912. In making the computations the rows were grouped to represent repeated plantings of one kind of material without regard to their former use as checks.

The relative merits of the different numbers of replications studied were determined from their reduction of the experimental error which arises from uncontrollable factors of the environment, such as irregularities in fertility, drainage, etc. The reduction was based upon a diminution of the difference in crop yields between a unit area of ground and one half of two similar laterally contiguous areas when replications were used in gradually augmented numbers, the middle area being designated as a standard of comparison, or more briefly as a standard, the two lateral areas as adjacent areas. One set of three such areas (a standard and two adjacent areas) was used to represent a single planting, two sets were used for two replications, three sets for three replications, four sets for four replications, etc., i. e., the number of sets corresponded to the number of replications. To compute a single deviation of the laterals from the standards for any number of replications, the average yield of its lateral areas was subtracted from the average yield of its standard and the deviation so obtained was used without regard to its plus or minus sign. Several hundred different deviations were thus computed for each number of replications and from these separate determinations its average or arithmetic mean was calculated. These mean deviations of the laterals from the standard, i. e., mean deviation for each number of replications, show the gradual reduction of the experimental error obtained by means of increasing numbers of replications.

Each standard area and its two laterally continguous areas were represented by three consecutive former check rows and the deviation of the laterals from the standard or central row was determined from their yields. To illustrate, let us consider row 3 as the first standard and rows 1 and 5 as its laterally adjacent pair of rows. If the yield of row 3 is 4,962 grams of sugar and that of rows 1 and 5 is 3,793 and 4,571 grams respectively, then the deviation of the adjacent pair of rows from this standard is $\frac{3{,}793 + 4{,}571}{2} - 4{,}962$, or 780 grams.

Three hundred deviations were thus computed from as many different sets of three rows and the mean calculated from the total number of these determinations. This represents the mean deviation of the adjacent pairs of rows from their standards for a single planting.

Consecutive Replications with Checks.

The method of grouping the rows in consecutive replications to determine a single deviation of the adjacent pairs of rows from their standards is shown for one group of duplicate plantings in Table 6.

Table 6.—*Combinations of standards and their adjacent pairs of rows in one group of duplicate plantings.*

Standards.		Adjacent rows 32 inches from standards.		Deviation in grams.
Row numbers.	Yield in grams.	Row numbers.	Yield in grams.	
3	4,962	1	3,793	
		5	4,571	
7	4,520	5	4,571	
		9	5,600	
Average	4,741		4,633	108

To compute the deviation of the adjacent pairs of rows from their standards, the yields of the standards were added together and also the yields of the adjacent pairs of rows, and each sum divided by the number of rows which contributed to it (see Table 6), in order to reduce the results to a one row basis. The difference in the average yields per row, 108 grams, represents the deviation in grams of sugar. Three hundred similar groups of duplicate plantings were used, each represented by two standards, as 3, 7; 5, 9; 7, 11; 9, 13; 11, 15[5]; or some other pair of this sequence and two pairs of adjacent rows and the deviation of the adjacent pairs from the standards determined for each group. From the 300 deviations thus obtained, the mean deviation of the adjacent pairs of rows from the standards was calculated for two replications.

The mean deviation of the adjacent pairs of rows from the standards for three or more consecutive replications was calculated by means of the same system employed for duplicate plantings. For instance, in five replications, rows 3, 7, 11, 15, and 19 were used as standards in the first group; rows 5, 9, 13, 17, and 21 as standards in the second group; and rows 7, 11, 15, 19, and 23 as standards in the third group. Whatever the number of replications, the number of standards and the number of pairs of adjacent rows used in each group to determine a single deviation always corresponded to it.

By use of the described plan, the mean deviation of the adjacent pairs of rows from the standards was determined for each of a series of consecutive replications ranging from 1 to 10. The mean devia-

TABLE 7.—*Effect of repeated plantings on the deviation of the adjacent pairs of rows from the standards in grams of sugar when repetitions occur in succession.*

	Weight class.	Number of replications.									
		1	2	3	4	5	6	7	8	9	10
	Grams.			Number of deviations.							
Deviations in grams of sugar.	0– 99	54	97	112	109	117	116	138	132	141	148
	100– 199	55	80	75	76	91	98	82	90	75	62
	200– 299	45	40	43	54	46	35	28	29	25	30
	300– 399	39	35	33	23	16	18	16	19	28	24
	400– 499	31	16	16	13	9	8	12	8	6	6
	500– 599	24	16	8	10	5	9	5	3	1	1
	600– 699	16	6	4	2	9	2	1	1	2	
	700– 799	10	3	4	5	1	2	2			
	800– 899	12	4	3	3						
	900– 999	6	—	2	1	—	1				
	1,000–1,099	2	2	1							
	1,100–1,199	—	1	1							
	1,200–1,299	3	—								
	1,300–1,399	1	—	1							
	1,400–1,499	1	[a]**1**								
	1,500–1,599	1	**1**								
	1,600–1,699										
	1,700–1,799	—	**1**								
Total		300	(303) 300	303	296	294	289	284	282	278	271

[a] The figures in boldface type were not used in calculating constants.

[5] The only advantage in overlapping groups is that it affords a large number of combinations with a relatively small number of rows.

tions and the frequency distributions from which they were derived are shown in Table 7.

	Mean deviation.	Standard deviation.
One replication	356.17 ± 11.02	283.00 ± 7.79
Two replications	225.83 ± 7.85	201.51 ± 5.55
Three replications	211.88 ± 7.98	205.94 ± 5.64
Four replications	196.46 ± 6.87	175.12 ± 4.85
Five replications	169.57 ± 5.79	147.22 ± 4.09
Six replications	165.07 ± 5.80	146.23 ± 4.10
Seven replications	147.74 ± 5.39	134.65 ± 3.81
Eight replications	140.99 ± 4.66	116.08 ± 3.30
Nine replications	139.43 ± 4.82	119.23 ± 3.41
Ten replications	131.79 ± 4.56	111.27 ± 3.22

The mean deviation in yield of sugar between the adjacent pairs of rows and the standards diminishes with some regularity and rapidity up to the seventh replication but thereafter the decrease is less rapid. This is illustrated graphically in figure 2, where the empirical means for the total number of replications are plotted and connected by straight lines.

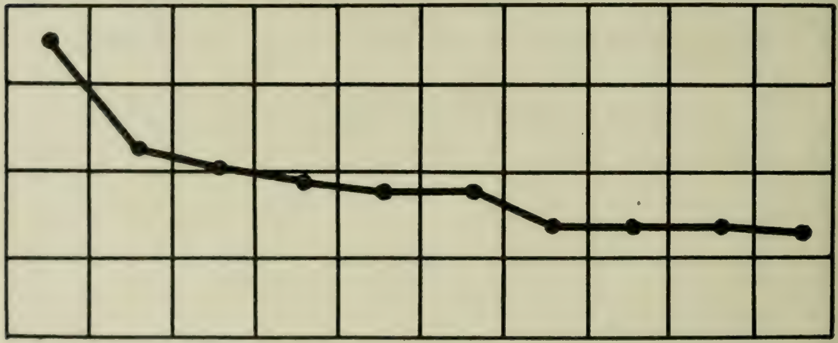

FIG. 2. Graph showing relationship between mean deviations and number of replications. Squares from left to right represent replications from 1 to 10; squares from bottom to top represent deviations in grams of sugar, the classes being 0–99, 100–199, 200–299, and 300–399 grams respectively.

As shown in the graph and also in Table 7, the use of ten replications reduced the mean deviation from the standards about 224 grams (356–132), or 176.7 grams in excess of four times the probable error, which amounts to about 50 percent reduction in the experimental error.

DISTRIBUTED REPLICATIONS WITH CHECKS.

When the replications were distributed in different parts of the field, they were arranged as shown in figure 3.

In the case of duplicate plantings, or two replications, the strips were used in pairs, as 1, 1; 2, 2; and 3, 3, as indicated by the numerals on the arrows, the combinations of rows, i. e., the first standard and its two lateral rows, for each pair of strips beginning at the points marked by the arrows and continuing in the directions indicated. For instance, rows 1 and 542 were used as standards for the first group in strips 1; rows 111 and 223 as standards for the first group in strips 2; and rows 330 and 437 as standards for the first group in strips 3.

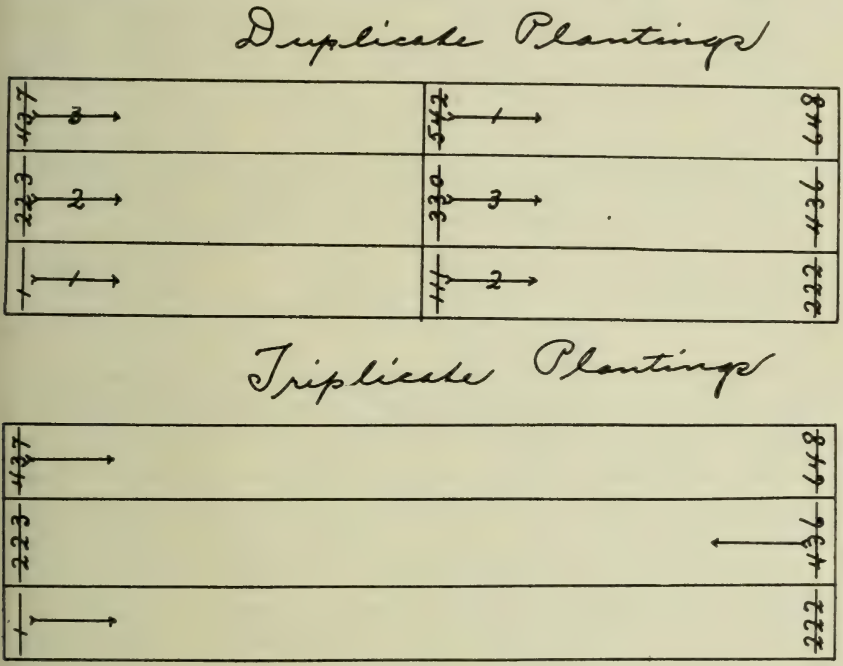

FIG. 3. Diagrams showing locations of distributed replications.

When making combinations of rows to represent triplicate plantings, or three replications, one standard and its adjacent pair of rows was always used from each strip. The arrows indicate the location of the rows used in the first group and the order in which rows were used to form subsequent groups. To be more specific, the standards were represented by rows 1, 436, and 437 in the first group, by rows 3, 434, and 439 in the second, etc.

By means of the foregoing plan, the mean deviation of the adjacent pairs of rows from the standards was calculated for duplicate and triplicate plantings distributed over different parts of the field. The mean deviations and the frequency distributions from which they were derived are given in Table 8.

TABLE 8.—*Effect of repeated plantings on the deviation of adjacent pairs of rows from the standards in grams of sugar when repetitions are distributed to secure average soil conditions.*

Weight class.	Number of replications.			Weight class.	Number of replications.		
	1	2	3		1	2	3
Grams.				*Grams.*			
0– 99	54	23	28	1,000–1,099	2	1	
100–199	55	39	29	1,100–1,199	–	–	
200–299	45	32	11	1,200–1,299	3	–	
300–399	39	25	12	1,300–1,399	1	[a]1	
400–499	31	14	9	1,400–1,499	1	–	
500–599	24	13	9	1,500–1,599	1	–	
600–699	16	4	1	1,600–1,699	–	–	
700–799	10	1	1	1,700–1,799	–	[a]1	
800–899	12	1	1				
900–999	6	1	–	Total..........	300	154 (156)	101

[a] Figures in boldface type were not used in calculating constants.

	Mean deviation.	Standard deviation.
One replication	356.17 ± 11.02	283.00 ± 7.79
Two replications	281.32 ± 10.28	189.22 ± 7.27
Three replications	236.63 ± 12.41	184.91 ± 8.78

A comparison of the mean deviations shows that the experimental error is diminished considerably by the use of three replications. Although the mean deviation for three distributed replications, i. e., replications distributed over the field, is 236.63 grams, while for three consecutive replications it is only 211.88 grams (Table 7), the difference of 24.75 (± 14.75) grams is only apparent as it is less than twice its probable error. The two kinds of distributions give practically the same diminution of the experimental error. Therefore no advantage is obtained by distributing replications to secure average soil conditions so long as the comparison is to be made with check rows and only the relative difference in yield is sought. While this method may give a closer approximation to actual field yields than consecutive replications, it is doubtful whether acre yields should ever be calculated from such small areas unless the number of repetitions is large and several fields are included in the experiment.

SUMMARY.

1. The practice of dispensing with check rows and using the mean of all progeny rows as a standard of comparison as shown in Tables 2 and 3, appears to be less efficient than the employment of frequent checks.

2. Check rows 32 inches from the progeny row varied less than those

at distances of 64, 96, 128, and 160 inches. The last four distances appeared to be equally good for checks when compared with due regard to probable errors.

3. The employment of every alternate row as a check was not sufficient to offset the variability in yield arising from irregularities of the soil.

4. By means of ten replications and alternate check rows the experimental error was reduced about 50 percent. The reduction was most rapid in the first seven repetitions and decreased slowly in subsequent plantings.

CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM IN THE DRAINAGE WATER FROM LIMED AND UNLIMED SOIL.[1]

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Introduction.

The soil used in twelve of the lysimeter tanks at Cornell University contains about equal quantities of calcium and magnesium in the upper 3 feet, but in the fourth foot there is considerably more calcium. There is on the whole a tendency for the percentages of these constituents to increase with the depth. In respect to potassium the surface foot has a smaller quantity than the succeeding 3 feet, each of which contains approximately the same percentage. The percentages of sodium are fairly constant for each of the 4 feet. The soil, which is a Dunkirk clay loam, was placed in the tanks in the same 1-foot layers in which it was removed from the field. A partial analysis of the solution of the entire soil obtained by digestion with hydrofluoric and sulfuric acids is given in Table 1.

Table 1.—*Content of lime, magnesia, potash, and soda in each foot of soil in lysimeter tanks, expressed in percentages in dry soil.*

Constituent.	Percentages at various depths.			
	First foot.	Second foot.	Third foot.	Fourth foot.
Calcium oxide (CaO)	0.34	0.28	0.48	1.50
Magnesium oxide (MgO)	0.35	0.45	0.52	0.59
Potassium oxide (K_2O)	1.81	2.32	2.57	2.44
Sodium oxide (Na_2O)	0.85	0.85	0.72	0.80

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[1] Contribution from the Department of Soil Technology, Cornell University. Received for publication January 24, 1916.

Drainage water resulting from the natural rainfall was collected, measured, and analyzed twice yearly through a period of five years. The treatments given the tanks discussed in this paper are shown in Table 2.

The application of farm manure was uniform for all tanks. Burned lime was applied at the rate of 3,000 pounds per acre to the tanks designated in Table 2 (7, 8, 9, 10, and 12). The application was made only once, at the beginning of the experiment. Potassium sulfate was applied annually to Tanks 11 and 12.

TABLE 2.—*Treatment given to lysimeter tanks and crops grown therein.*

Tank No.	Treatment.	Crops grown.
3	Farm manure	Maize, oats, wheat, timothy two years.
4	Do	Kept bare of vegetation continually.
5	Do	Maize, oats, wheat, timothy and clover.
6	Do	Maize, oats, mixed grasses three years.
7	Farm manure and lime	Same crops as Tank 3.
8	Do	Kept bare of vegetation continually.
9	Do	Same crops as Tank 5.
10	Do	Same crops as Tank 6.
11	Farm manure and sulfate of potash	Same crops as Tanks 3 and 7.
12	Farm manure, lime, and sulfate of potash	Same crops as Tanks 3, 7, and 11.

The relative quantities of the bases in the drainage water indicates the retentiveness of the soil for these substances and may give some idea of how the composition of the soil differs from the composition of the soil water with which the plant roots came in contact. While it is probably not the case that the soil water in the first foot of soil has a composition similar to that which issues from the bottom of the fourth foot, it is nevertheless probable that the drainage water represents the relative composition of the soil water more closely than does the composition of the soil.

MAGNESIUM IN THE DRAINAGE WATER.

The ratio of calcium to magnesium that obtains in the drainage water from these tanks is quite different from that in the soil. Thus in the drainage from the soil receiving no commercial fertilizer and no lime, the calcium magnesium ratio is 5.4 : 1. This is a very different ratio from that which exists in the soil itself, and affords a solution that is not near the point where magnesium would exert a toxic action on plant growth.

The effect of lime when applied to this soil is to narrow this ratio in the drainage, reducing it to 4.4 : 1. This is the average for the drainage from four tanks treated similarly to the four mentioned above, except for the application of lime. Instead of increasing the proportion of calcium in the drainage the effect of liming is to decrease it. How far this would go with greater applications of lime can not be ascertained from these experiments.

Lime applied to this soil at the rate of 3,000 pounds of burned lime to the acre has not resulted in increasing the actual quantity of calcium in the drainage water during the five years that the drainage has been collected. On the other hand, the quantity of magnesium in the drainage from the limed soil has been appreciably affected. This is shown in Table 3.

TABLE 3.—*Annual average number of pounds per acre of calcium and magnesium in drainage from limed and unlimed soil for a 5-year period.*

Tank Nos.	Soil treatment.	Calcium (Ca).	Magnesium (Mg).
3, 4, 5, 6	Not limed	225.5	40.3
7, 8, 9, 10	Limed	218.2	47.7

There would seem to be, in this case, a liberation of magnesium produced by the application of calcium.

POTASSIUM IN THE DRAINAGE WATER.

The ratio of calcium to potassium in the drainage water from this soil is broadened by the application of lime. In the drainage from the unlimed soil the ratio is 4.2 : 1, while in that from the limed soil the ratio is 4.7 : 1. The action of the lime application on the calcium-potassium ratio is therefore diametrically opposite to its influence on the calcium-magnesium ratio, but quantitatively the effect is less.

As is to be expected from these ratios the actual quantity of potassium in the drainage from the limed soil is less than that in the drainage from the soil that received no lime, as shown by Table 4.

TABLE 4.—*Annual average number of pounds per acre of calcium and potassium in drainage from limed and unlimed soil for a 5-year period.*

Tank Nos.	Soil treatment.	Calcium (Ca).	Potassium (K).
3, 4, 5, 6	Not limed	225.5	53.0
7, 8, 9, 10	Limed	218.2	46.3

If there is any liberation of potassium by lime, the potassium must have been absorbed by the lower layers of soil and thus did not appear in the drainage water. While there is no indication that potassium was set free by the lime treatment, it is quite probable that if this had been the case the potassium would have been absorbed before it escaped in the drainage water, for the application of a potassium salt did not result in increasing the quantity of potassium in the drainage. Thus when two tanks that received an annual application of potassium sulfate at the rate of 200 pounds to the acre are compared with tanks not receiving any potassium but otherwise similarly treated, there is found to be no more potassium in the drainage water from the soil receiving potassium than from the soil that received none. (Table 5).

TABLE 5.—*Annual average number of pounds per acre of calcium and potassium in drainage from soil that received an annual application of potassium sulfate for a 5-year period.*

Tank Nos.	Soil treatment.	Calcium.	Potassium.
3	No lime, no potassium	200.7	52.7
11	No lime, potassium	213.1	43.7
7	Lime, no potassium	167.8	43.7
12	Lime, potassium	199.7	40.3

It is evident from these figures that there was an absorption of the potassium applied that left no excess in the drainage water. Any liberation of potassium by lime would therefore be only temporary and the potassium would soon be reabsorbed.

POTASSIUM IN THE CROPS.

Although the drainage water showed no evidence of liberation of potassium by lime, the possibility still remains that a greater removal by plants of potassium from the limed soil would prevent the appearance in the drainage water of that set free. As the potassium content of the crops raised on these tanks for four years has been determined a comparison of the quantities of potassium removed by the plants that grew on the limed and unlimed soils may be made, as shown in Table 6.

TABLE 6.—*Annual average number of pounds per acre of potassium in crops raised on limed and on unlimed soil for a 4-year period.*

Tank Nos.	Soil treatment.	Potassium in crops.
3, 5, 6	Not limed	80.1
7, 9, 10	Limed	77.5

When both lime and potassium sulfate were applied to the soil, the crops produced contained slightly more potassium than did crops raised on soil that received potassium sulfate but no lime. This difference, however, is probably within the limit of experimental error as is indicated by a comparison of these with other figures from the limed and unlimed soils as shown in Table 7.

TABLE 7.—*Annual average number of pounds per acre of potassium in crops raised on soil that received an annual application of potassium sulfate for a 4-year period.*

Tank Nos.	Soil treatment.	Potassium in crop.
3	No lime, no potassium	91.1
11	No lime, potassium	77.6
7	Lime, no potassium	83.6
12	Lime, potassium	84.0

The indications, on the whole, are opposed to the conclusion that potassium is liberated by the application of lime to this soil, where the quantity used corresponds to the lime requirement of the surface foot, as determined by the Veitch method.

SODIUM IN THE DRAINAGE WATFR.

The effect of liming this soil on the ratio of calcium to sodium in the drainage water is similar to its effect on the calcium-potassium ratio. The ratio for the unlimed soil is 2.3: 1, and for the limed soil, 2.8: 1. These ratios are much narrower than are the calcium-potassium ratios, indicating a larger quantity of sodium in the drainage water. This is borne out by the figures for total flow shown in Table 8.

TABLE 8.—*Annual average number of pounds per acre of calcium and sodium in drainage from limed and unlimed soils for a 5-year period.*

Tank Nos.	Soil treatment.	Calcium.	Sodium.
3, 4, 5, 6..........	Not limed	225.5	93.2
7, 8, 9, 10.........	Limed	218.2	75.8

The total quantity of sodium removed is much greater than the quantity of magnesium or of potassium. The effect of lime on this soil was to decrease appreciably the quantity of sodium removed in the drainage water.

EFFECT OF POTASSIUM SULFATE ON THE BASES IN THE DRAINAGE WATER.

As previously stated, two of the tanks received an annual application of potassium sulfate at the rate of 200 pounds per acre. The quantities of bases in the drainage water from these tanks and from other tanks receiving no potassium but on which crops were raised are shown in Table 9.

TABLE 9.—*Pounds per acre of calcium, magnesium, potassium, and sodium in drainage from soil treated with potassium sulfate and from untreated soil.*

Tank Nos.	Soil treatment.	Constituents in drainage water.				Total.
		Calcium.	Magnesium.	Potassium.	Sodium.	
3, 5, 6	No lime, no K_2SO_4	177.1	33.8	46.3	83.5	340.7
11	No lime, K_2SO_4	213.1	49.2	43.7	84.1	390.1
7, 8, 9	Lime, no K_2SO_4	169.6	40.2	45.5	73.4	328.7
12	Lime, K_2SO_4	199.7	47.1	40.3	79.8	366.9

The application of potassium sulfate increased in each case the quantities of calcium and magnesium, and in less degree the quantity of sodium in the drainage water. It is doubtful whether the increase in sodium is not within the experimental error. The relative increase of these three constituents is shown in Table 10.

TABLE 10.—*Increase of calcium, magnesium, and sodium in drainage when soil which received no potassium sulfate is taken as 100.*

Tank Nos.	Soil treatment.	Calcium.	Magnesium.	Sodium.
3, 5, 6	No lime, no K_2SO_4	100	100	100
11	No lime, K_2SO_4	120	146	101
7, 9, 10	Lime, no K_2SO_4	100	100	100
12	Lime, K_2SO_4	118	117	109

Magnesium appears to be freely liberated from this soil both by lime and by the potassium salt, but especially by the latter. These substitutions of bases are doubtless a factor in the effects produced on the soil by fertilizers and other inorganic salts.

One marked difference between the effect of lime and of potassium sulfate when applied to this soil is that an application of the former resulted in a decrease in the sum total quantity of the bases calcium, magnesium, potassium, and sodium in the drainage water, while the applications of potassium sulfate increased the sum total loss of these bases. The fact that the application of potassium was combined with a strong acid (sulfuric), whereas the lime was in the form of an oxide, would probably account at least in part for this, as the quantity of sulfate was larger in the drainage water from the soil that received potassium sulfate.

CONCLUSIONS.

Of the bases, calcium, magnesium, sodium, and potassium, the last named is most firmly held in the soil used in this experiment.

An application of burned lime corresponding to the lime requirement of the surface foot of soil was not accompanied by any appreciable increase in the quantity of potassium present in the drainage water.

The application of lime did not result in any greater quantity of potassium in the crops raised on the limed soil than in those that grew on the soil that received no lime.

So far as could be ascertained from the potassium in the drainage water and the crops raised on the soil treated with lime and the soil not so treated, there was no liberation of potassium effected by the lime treatment.

Magnesium was the only one of the four bases that appeared in larger quantity in the drainage from the limed than from the unlimed soil.

The calcium-magnesium ratio is much broader in the drainage water from this soil than in the soil itself.

The effect of an annual application of potassium sulfate at the rate of 200 pounds per acre was to increase materially the quantity of calcium and magnesium in the drainage water, but not to increase the quantity of potassium.

The sum total quantity of the bases calcium, magnesium, potassium, and sodium was less in the drainage water of the soil that received an application of lime than in the water from the unlimed soil.

THE LOSS OF SULFUR IN DRAINAGE WATER.[1]

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The recent interest concerning the supply of sulfur in soils and its possible need as a constituent of fertilizers suggests the desirability of publishing at this time some data on the content of sulfates in the drainage water from soil contained in the lysimeter tanks erected at Cornell University in 1908. Five crops have now been grown in these lysimeters and the sulfate content of the drainage water for four years is available. The soil from which these data are derived is known as Dunkirk clay loam. It is a soil of good fertility when properly tilled, although somewhat likely to become compact on account of its high proportion of fine particles. However, there has been no difficulty in securing good drainage from the lysimeters. These tanks are each 4 feet, 2 inches square and 4 feet deep, and thus contain about 3.5 tons of soil. The drainage water is collected and measured and samples representing the entire flow are analyzed.

Not many data have been published that indicate the loss of sulfur in drainage water. Hanamann[2] reports the results of experiments with lysimeters in which several soils were placed and drainage collected from soil cropped and uncropped. The period during which the drainage was collected was from April 1 to October 30 of one year. The quantity of sulfur in the drainage water for this period was 44 pounds per acre from a basalt soil and 37 pounds from an alluvial soil, both of which remained bare of vegetation during the entire period. Crops were grown on the alluvial soil. From the lysimeter on which maize was grown there were 29 pounds and from the lysimeter on which red clover was grown there were 15 pounds per acre of sulfur in the drainage water.

Norton[3] estimated sulfur among other constituents in the drain-

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[1] Contribution from the Department of Soil Technology, Cornell University. Received for publication January 24, 1916.

[2] Hanamann, J. Lysimeter Versuche. Ztsch. Landw. Versuchsw. Oesterr., 1: 399-410. 1898.

[3] Norton, J. H. Quantity and Composition of Drainage Water, and a Comparison of Temperature, Evaporation and Rainfall. Jour. Amer. Chem. Soc., 30: 1186-1190. 1908.

age basin of Richland Creek, Arkansas. The area drained was 84,954 acres of agricultural land that had never received any commercial fertilizer. His method was to measure the stream every two weeks from January 6 to December 23, and at the same time to take a sample of water for analysis. The quantity of sulfur in the drainage for the period mentioned was 7.1 pounds per acre. Hart and Peterson[4] estimate from figures given by Hall that the annual loss of sulfur in drainage water from the Rothamsted soils is from 20 to 80 pounds per acre, depending on the fertilizer treatment.

As the data on the subject are rather meager, any further contribution, even though it represents drainage from only one soil, will probably be of interest to those who are studying the relations of sulfur to agricultural soils. It has been assumed in these experiments that all of the sulfur in the drainage water is in the form of sulfates, as there is no appreciable quantity of organic matter present in the drainage from this soil. The drainage from ten lysimeters will be discussed in this paper. Five of these were given an application of lime in 1910 at the rate of 3,000 pounds to the acre. Four of the unlimed tanks and four of the limed were planted to some crop each year. Of these, one of each received an annual application of 200 pounds of sulfate of potash per acre. One of the unlimed and one of the limed lysimeters were kept free of vegetation during the entire period. These treatments, together with the quantities of sulfates expressed as sulfur which were found in the drainage water, are shown in Table 1.

TABLE 1.—*Treatments and crops grown on ten lysimeter tanks at Cornell University from 1910 to 1914, with the sulfur found in the drainage water therefrom expressed in pounds of sulfates per acre.*

Tank No.	Treatment.		Crops grown.				Sulfur as sulfates (pounds per acre).	
	Lime.	Fertilizer.	1910.	1911.	1912.	1913–14.	1911–14.	Annual average.
3	None	None	Maize	Oats	Wheat	Timothy	127.2	31.8
4	do	do	None	None	None	None	176.1	44.0
5	do	do	Maize	Oats	Wheat	Timothy and clover	126.2	31.5
6	do	do	do	do	Grasses	Grasses	172.8	43.2
7	Lime	do	do	do	Wheat	Timothy	175.7	43.9
8	do	do	None	None	None	None	212.6	53.1
9	do	do	Maize	Oats	Wheat	Timothy and clover	164.2	41.0
10	do	do	do	do	Grasses	Grasses	151.0	37.7
11	None	Sulfate of potash	do	do	Wheat	Timothy	225.7	56.4
12	Lime	do	do	do	do	do	248.1	62.0

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[4] Hart, E. B., and Peterson, W. H. Sulfur Requirements of Farm Crops in Relation to Soil and Air Supply. Wis. Agr. Expt. Sta. Research Bul. 14, p. 16. 1911.

It may be further explained that while sulfate of potash was the only commercial fertilizer applied to any of the lysimeters, all received an application of 10 tons of farm manure at the beginning of the experiment and again in 1914. These two applications contained 124 pounds of sulfur per acre, of which 27.2 pounds were in the form of sulfate.

It may be considered that the drainage from Tank 4 represents the loss of sulfur from an unlimed and unplanted soil, and one that had received only a small addition of sulfate. The sulfur in the drainage water from this tank was 176 pounds per acre for the four years, or an average of 44 pounds per year.

Tank 8, like Tank 4, was kept free from vegetation during the entire period, but differed from Tank 4 in having had an application of burned lime. The lime treatment appears to have been accompanied by an increased removal of sulfur, as the drainage water contained 212.6 pounds per acre of sulfur in four years or a yearly average of 53.1 pounds. The annual loss from the limed soil is thus about 9 pounds per acre more than from the unlimed soil.

Following up the effect of lime on removal of sulfur from the planted tanks, we find that the average loss of sulfur from the unlimed but planted tanks, 3, 5, and 6, was 35.5 pounds per acre annually, while from the similarly cropped but limed tanks, 7, 9, and 10, the loss of sulfur amounted to 40.9 pounds. The greater removal of sulfur accompanying the application of lime was therefore about 5 pounds.

Finally, comparing Tanks 11 and 12, both of which had an annual application of sulfate of potash but only one of which was limed, the greater loss from the limed soil is found to be about 5.5 pounds per acre annually. A comparison of all the limed and all the unlimed tanks shows a greater loss of sulfur from the limed soil amounting to about 6 pounds per acre annually. It would thus appear that, at least on this soil, one effect of liming is to increase the removal of sulfur in the drainage water.

A comparison of the drainage from planted and unplanted lysimeter tanks shows, as is to be expected, a smaller removal of sulfur from the planted tanks. Thus the decrease due to cropping was 8.5 pounds per acre for the unlimed tanks and 12 pounds per acre for the limed ones.

The fate of sulfate applied to the soil is in part indicated by these experiments. Tanks 11 and 12, each of which received an annual application of 200 pounds per acre of commercial sulfate of potash, equivalent to about 35 pounds of sulfur, suffered a loss of 56.4 and 62.0 pounds of sulfur respectively in the annual drainage. This is decidedly the greatest quantity of sulfur in the drainage water from any of the tanks and is respectively 24.6 and 18.1 pounds per acre more than the quantities removed from Tanks 3 and 7, which were treated in a similar manner except for the application of sulfate.

From these figures it may be inferred that from one-half to two-thirds of the total sulfur added in the form of sulfate was removed in the drainage water. As compared with most substances added to the soil as a fertilizer this is a large loss. It raises the question whether the use of sulfates as a source of sulfur is economical, and whether it is not better to supply this material in the form of organic matter. It is true that sulfate is frequently present in fertilizers as an accidental constituent and adds nothing to the cost of the material. This being the case, its loss in drainage water is not a matter of importance. It must be remembered, however, that in some forms it may greatly increase the loss of lime.

On the soil used in these experiments, the use of potassium sulfate did not increase the yield of crop. It is probable that the soil did not require more sulfur than it naturally possessed plus what had been added in manure.

The results of these experiments may be summarized as follows:

1. The sulfur removed in the drainage water from an unplanted, unlimed soil that had received some farm manure but no commercial fertilizer amounted to 44 pounds per acre annually.

2. The application of lime increased the quantity of sulfur removed by the drainage water.

3. Soil on which crops were grown lost less sulfur in the drainage water than did unplanted soil when otherwise similarly treated.

4. The annual application of sulfate of potash at the rate of 200 pounds per acre markedly increased the quantity of sulfur in the drainage water.

5. From one-half to two-thirds of the sulfur applied annually as sulfate of potash was removed in the drainage water.

MOISTURE CONTENT AND SHRINKAGE OF FORAGE.[1]

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Introduction.

The relation of the amount of moisture in hay at the time it is put into the stack or mow and that which it contains when taken out for sale or for feeding some months later has been investigated at various times by a number of experiment stations. In some instances the determinations were made by weighing the hay at the time it was stacked or put into the barn and again when it was taken out, the difference being considered as loss of moisture. In other cases the moisture content of the hay was determined by sample, the difference in the moisture content at time of putting up the hay and of samples taken later being considered as representing the loss of moisture in the bulk. Some investigators report the loss during storage merely as shrinkage, but most of those who have studied the problem assume that the loss is of moisture only and have so reported it. A few experiment stations have studied the moisture content of forage plants at different stages of development, and some tests (18)[2] have been conducted to determine the rate of loss of moisture in very early stages of curing, beginning immediately after cutting. One or two workers have also begun investigations to ascertain a satisfactory method for correcting forage yields (10, 19) and a little work has been done in determining the amount of shrinkage which can be attributed to an actual loss of dry matter. The data on these last-named points are very inadequate, so that more information is much needed.

A mass of information on moisture content is also contained in reports of the chemical analyses of both green and field-cured forage plants, but unfortunately care is not always used by the chemist to protect the sample from drying after it has been brought into the laboratory. This is due to the fact that the percentages of food constituents are often computed on a dry-matter basis and the percentage of moisture in the sample is therefore only incidental.

[1] A digest of the literature relating to the moisture content and shrinkage of forage. Received for publication December 15, 1915.

[2] Figures in parentheses refer to publications similarly numbered in the literature cited at the end of this paper.

OISTURE CONTENT IN RELATION TO STAGE OF GROWTH.

nnection with studies of the chemical content of plants at vari- c ges of growth, considerable data have been recorded concern- i r water content. These data and others, so far as they refer to ite stages of development, are compiled in Table I.

T I.—*Percentages of moisture in forage plants at different periods of their growth.*

TIMOTHY.

and source of data.	Heads not yet visible.	Heads just appearing.	Heads fully out.	Beginning to bloom.	Full bloom.	Bloom past.	Nearly ripe.	Seed fully formed.	Seed becoming hard.
Conn. (2, p. 31)	—	—	61.72	—	66.83	59.89	55.29	—	—
Me. (13, p. 42)	—	—	78.70	—	71.92	65.20	63.27	—	—
U. S. Dept. Agr. (22, p. 133)	70.70	71.90	67.50	64.90	67.20	—	—	—	—
Do.	—	—	78.56	—	66.75	58.86	—	—	—
U. S. Dept. Agr. (22, p. 134)	70.00	—	67.50	—	64.50	56.30	—	53.00	—
N. Y. (17, p. 413)	—	—	—	—	57.32	—	—	—	46.98
Do.	—	—	—	—	59.85	—	—	—	48.68
Do.	—	—	—	—	59.77	—	—	—	48.78
N. H. (20, p. 64–65)	82.51	70.39	—	66.11	—	58.77	—	55.51	52.17
Penn. (14, p. 7–8)[a]	—	76.54	—	69.08	—	59.87	—	—	—
Average	74.40	72.94	70.80	66.70	64.27	59.82	59.28	54.25	49.15

ALFALFA.

Crop and source of data.	Height 18 inches.	In bud.	Early bloom.	Half bloom.	Full bloom.	Bloom fading.	Leaves drying.	Fully ripe.
[illegible]S. Dept. Agr. (3, p. 152)	80.40	79.30	—	—	70.10	—	—	—
[illegible]n. (1, p. 135)	—	73.34	—	—	70.83	—	—	62.54
. (21, p. 11)	—	77.65	—	—	69.71	60.89	—	49.30
Utah (33, p. 75)	84.76	79.77	78.66	77.86	73.96	70.66	66.67	—
Do.	—	83.29	79.77	79.11	75.04	73.31	73.46	—
Do.	84.81	80.95	77.47	—	—	—	—	—
K[illegible]ns. (27, p. 258)	—	—	74.64	69.72	64.18	—	—	—
Do.	—	—	78.65	70.65	—	—	—	—
Average	83.32	79.05	77.84	74.34	70.64	68.29	65.07	55.92

RED CLOVER.

Crop and source of data.	Heads not yet visible.	Just before bloom.	Full bloom.	Nearly out of bloom.	Seed formed.	Nearly ripe.	First cutting in bloom.	Second cutting, young bloom.	Third cutting, young bloom.
Conn. (2, p. 32)	—	61.21	[b]47.13	64.72	—	61.05	—	—	—
U. S. Dept. Agr. (3, p. 151)	82.80	82.70	79.90	74.20	73.90	—	—	—	—
U. S. Dept. Agr. (3, p. 152)	82.30	—	73.40	—	63.70	—	—	—	—
Wis. (35, p. 210)	—	—	—	—	—	—	91.78	77.52	72.51
Average	82.55	71.96	66.81	69.46	68.80	61.05	91.78	77.52	72.51

[a] These percentages were calculated from the data given in the tables on the pag s cited.

[b] This was obviously a faulty sample or some mistake has been made in cal- cul ting the percentage. (H. N. V.)

A compilation of all the American analyses of feeding st made by Jenkins and Winton in 1891 (12). A summation data showing the moisture content of green and field-cured of some of our most common forage crops is given in Tabl

Many of these analyses were doubtless of samples that had unusually dry in the laboratory before analysis, as the percent moisture are lower than those commonly found in commercial

Table 2.—*Moisture content of green and field-cured forage.*

Crop.	Green material.				Field-cured hay or fodd		
	Number of analyses.	Average.	Maximum.	Minimum.	Number of analyses.	Average.	Maximum.
		Percent.	*Percent.*	*Percent.*		*Percent.*	*Percent.*
Alfalfa	23	71.75	82.03	49.30	21	8.44	16.00
Red clover	43	70.79	91.78	47.13	38	15.26	31.27
Timothy	56	61.58	78.70	46.98	68	13.18	28.88
Kentucky bluegrass	18	65.07	82.53	51.67	14	21.16	32.82
Corn	126	79.33	93.60	51.50	35	42.18	60.17
Sorghum	11	79.40	86.38	63.88	—	—	—

Moisture in Hay when Placed in Storage.

The amount of moisture which is sometimes found in field-c hay at the time when it is stacked or placed in the mow is surpr ingly large. Instances where the moisture content was as high as percent in brome-grass, 36 percent in orchard grass, and 33 perc in alfalfa, when these hays were being stacked, are reported by Kansas Agricultural Experiment Station (28). Jordan reports percent of moisture in timothy when it was placed in the barn at Pennsylvania station (14). Unfortunately, it is not recorded in a of these instances whether the hay kept well in storage or not. I likely, however, that if decay took place this fact would have b mentioned. The average percentage of moisture in different kinds hay when placed in storage, as shown by the experiments at differ places, is 22.63 percent. This percentage is probably safe, but furt well-planned experiments are needed to determine how high the p centage of moisture in hay may be to allow its being stacked or sto without danger of spoiling. The data are compiled in Table 3.

Shrinkage in Weight During Storage.

The figures on shrinkage in different kinds of hay during stor vary so widely that they can be considered only as an indicatio what may be expected in actual practice. The published data on subject are compiled in Table 4.

TABLE 3.—*Moisture in hay when placed in storage.*

Description of hay.	Source of data.	Moisture content.
Small samples:		*Percent.*
Bluegrass	Kansas (9, p. 120)	18.21
Orchard grass and clover mixture	do	16.50
Millet	do	23.76
Clover	do	9.82
Prairie hay	do	12.55
Alfalfa, well cured, average of 19 bales	Kansas (29, p. 230)	6.20
Timothy, cut in 1908	Kansas (28, p. 330)	26.52
Timothy, cut in 1909	do	22.00
Average of percentages: Awnless brome grass, meadow fescue, orchard and tall oat-grass, cut in 1905	do	15.45
Same, cut in 1908	do	30.94
Same, cut in 1909	do	31.52
Alfalfa, average of first, second, third, and fourth cuttings (124 samples)	do	29.00
Timothy, cut when in bloom	Penn. (14, p. 13)[a]	36.16
Timothy, cut when nearly ripe	do	31.10
Timothy, redtop and red clover mixture:		
In 1901	R. I. (31, p. 129)	26.89
In 1902	R. I. (32, p. 72)	25.40
Average		22.63

[a] Calculated from figures on page cited.

The summarization in Table 4 indicates that a general shrinkage of about 18 percent may be expected in hay that is preserved in stacks or mows. The shrinkage in corn after it is shocked as fodder can not of course be fairly compared with the shrinkage in cured hay, because the corn is green when placed in the shock. The average shrinkage reported in a large number of determinations of corn fodder is 65.24 percent, the maximum being 78 percent. Accurate determinations of shrinkage of hay in the stack or mow are difficult to make, because large quantities of hay must be handled or the results will not be indicative of what is to be expected in actual farm practice. The moisture loss of hay stored in barns is apt to be greater and the loss of dry matter less in small quantities than in large quantities. In small stacks the extraneous influences, especially of the atmosphere, affect very largely the changes which take place within the stack. The results arrived at from studies of shrinkage carried out with only limited quantities of hay can not therefore be considered reliable.

SHRINKAGE IN DRY-MATTER CONTENT.

In the past, most investigators have considered that the loss of weight during storage was due entirely to the loss of moisture. This mistaken impression explains to a great extent why so few determina-

TABLE 4.—*Shrinkage in the weight of hay during storage.*

Crop and treatment.	Source of data.	Shrinkage.
Alfalfa:		*Percent.*
Cuttings Apr. 19 to Nov. 9 stacked in open until Feb. 11	Ariz. (34, p. 224)	11.00
Stacked in open 5 months	do	23.00
Stacked in open 8 months	Colo. (5, p. 7)	17.70
Stored in a barn 8 months	Colo. (5, p. 9)	12.20
Baled in good condition and stored in a barn 3 months	Kans. (29, p. 230)	6.20
Average loss		14.02
Timothy:		
Stored 10 months in a barn	Me. (16, p. 66)	17.35
Stored 6 months in a barn	Mich. (26, p. 160)	14.38
Stored in a barn until winter (average of a large number of determinations)	Penn. (14, p. 14)	25.40
Cut in bloom; stored in a barn 5 months	Penn. (15, p. 41 or 272)	25.70
Stored in a barn 9½ months	Utah (23, p. 46–49)	8.75
Stored in a barn 9 months	do	15.70
Average loss		17.88
Clover:		
Stored in a barn about 6 months (average of several determinations)	Mich. (26, p. 160)	11.60
Stored in a barn about 6 months	Penn. (14, p. 14)	24.50
Stored in a barn 5 to 6 months	Penn. (15, p. 43 or 274)	43.30
Samples buried in a stack and left until winter	Wye, England (30, p. 53)	15.87
Average loss		23.82
Timothy and clover:		
Stored in a barn 6 months (average of 4 determinations)	Penn. (14, p. 14)	20.5
Timothy, redtop, and red clover:		
Stored in a barn 6 months	R. I. (32, p. 73)	14.10
Average for all crops		18.06

tions of the dry-matter loss in hay have been made. The Utah station (23) found a loss of 13.03 percent dry matter in one instance and 10.19 percent in another when timothy was stored in a barn nine months. The same station also reports (23) that clover hay stored in a barn, stacked in the open, or suspended in sacks lost no dry matter. The Colorado station (5) reports a dry-matter loss of 10 percent for alfalfa stacked in the open eight months and 2.5 percent in alfalfa stored in a barn eight months. Outside of these few instances reported there seems to have been no investigation of the dry-matter loss of forage during storage except that of corn. The loss of dry matter in corn when it is shocked as fodder in the field or stored as ensilage in a silo is quite pronounced, and a considerable number of determinations of this factor have been made in Colorado, Vermont, Wisconsin, and Utah. The average loss in shocked fodder was 23.29 percent and the maximum loss found 43 percent. A less number of determinations of the dry-matter loss in ensilage averaged about the same, 20.77 percent, the maximum loss being 29.28 percent. This dry-matter loss was attributed by some investigators to fermentation, but apparently without any serious attempt to determine the nature of the ferments or even to prove the correctness of this view.

Complaint is often made by farmers that sorghum cut for fodder early in the season is of much less value as winter roughage for stock than that harvested later in the fall. It is very likely that the sorghums undergo even a greater dry-matter loss than corn while standing in shocks during the warm weather of summer and early fall. It has been found with corn that cold weather reduces the rate of dry-matter loss to a minimum, and this if true in the case of sorghum would explain the greater value of the late-harvested crop. Investigations in this field are much needed to discover the cause of this loss, the conditions tending to retard or accelerate it, and also to find how extensive it in in forage crops other than corn. The data relating to the total shrinkage and the dry-matter loss occurring in corn during storage as fodder and as ensilage are compiled in Table 5.

TABLE 5.—*Shrinkage of total weight and dry matter of corn during storage.*

Method of storing.	Source of data.	Shrinkage.	
		Total.	Dry matter.
Shocked as fodder:		*Percent.*	*Percent.*
In large shocks outdoors	Colo. (8, p. 24)	73.00	31.00
In small shocks outdoors	do	78.00	43.00
Indoors	Vt. (4, p. 94)	70.80	23.94
Outdoors	do	69.40	28.89
Do	Vt. (6, p. 79)	43.00	19.00
Do	Vt. (7, p. 180)	49.00	8.90
Whole plant, outdoors	do	——	18.00
Yellow dent, outdoors	Wis. (11, p. 69)	71.29	18.55
Average of 4 varieties, outdoors	Wis. (25, p. 128–129)	67.44	16.54
Average		65.24	23.09
Stover, outdoors	Vt. (7, p. 180)	——	17.00
Dry fodder stored in a barn	Utah (24, p. 33)	——	21.35
Stored as ensilage:			
Whole plant	Vt. (6, p. 79)	18.00	20.00
Stover	Vt. (7, p. 180)	——	21.00
Whole plant	do	——	18.00
Whole plant, sweet corn	Wis. (11, p. 71)	19.93	22.04
Whole plant, average of 3 varieties	Wis. (25, p. 128–129)	16.13	15.94
Whole plant	Utah (24, p. 33)	23.80	29.28
Average		19.47	21.04

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SOLUBILITY OF PLANT-FOOD ELEMENTS AS MODIFIED BY FERTILIZERS.[1]

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Introduction.

This paper deals with the seasonal changes in the water-soluble plant-food elements in a field of sugar beets at Rocky Ford, Colo., in 1912, together with the effect of fertilizers on the amounts of the various elements recovered. The soil used was a sandy loam which had been cropped to alfalfa for a number of years. The alfalfa was crowned in the fall of 1911 and plowed in the spring of 1912 to a depth of about 8 inches. The roots were removed as completely as possible and the ground planted to sugar beets in the first part of May.

Eight plots were laid out and fertilizers applied in the spring of 1912 at the following rates: Nothing; nitrate of soda, 300 pounds at time of planting and 300 pounds when the beets were thinned; calcium cyanamid, 500 pounds; superphosphate, 500 pounds; bone meal, 500 pounds; factory waste lime, 15 tons; composted manure, 14 tons; ordinary dry yard manure, 14 tons; yard manure, 14 tons plus 300 pounds ammonium sulfate. The sugar beets were cared for in the usual manner and were irrigated uniformly, usually about every 12 days. The composition of the yard manure and of the waste lime is given in Table 1. The CO_2, which was not determined in the lime, would bring the analysis up to practically 100 percent.

Soil samples to a depth of 12 inches were taken every week from May 16 to August 12. The samples were analyzed biweekly for the water-soluble P_2O_5, K_2O, SO_3, and Mn_2O_3. The fresh soils were extracted with distilled water in the proportion of one part of soil to five of water, filtered through Pasteur-Chamberlain filters and analyzed according to the methods given in Bulletin No. 31, of the U. S. Bureau of Soils. In addition to the above determinations, the nitrate nitrogen and the total nitrogen were determined each week. The results of the nitrogen measurements are given in another paper.[2]

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[1] Received for publication July 2, 1915.

[2] Jensen, C. A. Nitrification and Total Nitrogen as Affected by Crops, Fertilizers, and Copper Sulfate. Jour. Amer. Soc. Agron., 8: 10–22. 1916.

TABLE 1.—*Analysis of yard manure and of waste lime applied to sugar beets at Rocky Ford, Colo.*

Constituent.	Manure. *Per cent.*	Waste lime. *Per cent.*
Organic matter	37.96	8.00
Insoluble in HCl	43.63	17.95
SiO_2 (soluble)	.14	.38
Fe_2O_3	3.29	.88
Al_2O_3	4.16	2.25
CaO	3.88	38.57
MgO	.26	1.22
K_2O	2.54	.54
Na_2O	.67	.12
SO_3	1.18	.99
P_2O_5	.75	.68
N	1.52	.23

SOLUBILITY OF POTASH.

Table 2 shows the quantities of water-soluble K_2O found in the surface foot of the different plots. The various fertilizers added showed no effect on the seasonal average amounts of water-soluble potash, except in the case of the composted manure. The plots receiving this manure contained about twice as much water-soluble K_2O as any of the others. This may of course be accounted for to some extent by the presumably higher K_2O content of the composted manure, which had not been subjected to the leaching which occurs in manure as ordinarily handled in the district. It can hardly be supposed, however, that the increased supply of K_2O in the composted manure could account for 100 percent more water-soluble potash in the plots receiving this manure than was found in those receiving or-

TABLE 2.—*Water-soluble potash found on different dates in the surface foot of soil in plots variously treated, expressed in parts per million of K_2O.*

Treatment.	Dates.							Average.
	May 16.	June 3.	June 17.	July 8.	July 22.	Aug. 5.	Aug. 12.	
Nothing	91	55	35	25	55	45	40	49
Nitrate	61	45	49	10	55	38	45	43
Cyanamid	85	59	43	18	60	46	50	51
Phosphate	61	54	39	11	46	33	58	43
Bone meal	88	52	40	13	60	40	45	48
Waste lime	93	59	59	20	60	48	42	53
Composted manure	81	94	80	89	115	85	89	90
Dry manure	77	59	36	14	57	30	58	47
Manure + $(NH_4)_2SO_4$	72	52	34	13	59	40	72	49
Check on above	64	56	35	21	60	40	37	45
Averages	77	59	43	23	63	45	54	

dinary yard manure. The ordinary manure used contained, as shown in the analysis, 2.54 percent of K_2O. This would amount to over 200 parts per million of potash applied in the manure, whereas none of the plots receiving this manure showed any increase in the content of water-soluble K_2O over the checks. The results suggest that this composted manure had some effect, probably indirect, on the availability of the potash in the soil.

There were some striking changes in the quantities of water-soluble potash present as indicated by the averages at the bottom of Table 2, these quantities showing a marked decrease from May 16 to July 8. There was then a marked increase which continued fairly well for the rest of the experimental period. It is also of interest to note that the plot receiving the composted manure did not show such a seasonal decrease, but remained fairly constant throughout the season, excepting the high determination on July 22. This period of general decrease in soluble potash corresponds to the period of greatest increase in sugar-beet growth.

There was no correlation observable between the quantities of nitrate and of water-soluble potash determined, but the small differences in the average seasonal quantities of potash were correlated closely with similar differences in the average seasonal content of total nitrogen.

WATER-SOLUBLE PHOSPHORIC ACID.

Table 3 shows the amounts of water-soluble P_2O_5 found in the various plots.

Judging by the effect of bacterial activity on the solubility of phos-

Table 3.—*Water-soluble phosphoric acid found in different dates in the surface foot of soil in plots variously treated, expressed in parts per million of* P_2O_5.

Treatment.	Dates.						Average.
	May 16.	June 3.	June 17.	July 8.	July 22.	Aug. 12.	
Nothing	21	22	18	15	22	16	19
Nitrate	6	15	14	14	10	16	13
Cyanamid	20	26	32	16	21	18	22
Phosphate	13	17	17	13	5	17	14
Bone meal	17	26	18	21	32	25	23
Waste lime	14	18	13	11	30	25	19
Composted manure	20	15	20	13	8	16	15
Dry manure	27	18	21	10	18	25	20
Manure + $(NH_4)_2SO_4$	19	21	23	15	10	41	22
Check on above	20	20	16	12	18	35	20
Averages	18	20	19	14	17	25	

phates found by Sackett, Patten, and Brown[3] one might expect the manured plots, especially those treated with manure and ammonium sulfate, to show a greater amount of water-soluble P_2O_5 than the checks. Such, however, was not the case; in fact, it seems that the application of composted manure distinctly decreased the amount of P_2O_5 in soluble form. Again, the plots treated with superphosphate showed decidedly less water-soluble phosphorus than the checks, while the bone meal plots showed a little more and the nitrate plots less soluble phosphate than any others. It is of course possible that the plots showing the least soluble P_2O_5 really contained an abundance of available phosphate, the supply liberated having been taken up by the beets. It was found in another series of experiments, however, that none of the treatments caused an appreciable increase in available phosphorus. In the presence of a vigorous crop like sugar beets, it is admitted that such evidence is not conclusive regarding the effect on availability. While there was considerable variation from time to time in the quantity of phosphate, there was no such gradual seasonal decrease as was found in the case of nitrates and potash. No relation could be established between the quantities of water-soluble P_2O_5 and of nitrate, total nitrogen, or other elements discussed here, nor did the amount of soluble phosphates appear to be correlated with the yield.

SOLUBILITY OF SULFATES.

Table 4 shows the amounts of water-soluble sulfates expressed in parts per million of SO_3 in the soil.

TABLE 4.—*Water-soluble sulfates found on different dates in the surface foot of soil in plots variously treated, expressed in parts per million of* SO_3.

Treatment.	Dates.						Average.
	May 16.	June 3.	June 17.	July 8.	July 22.	Aug. 12.	
Nothing	230	100	175	140	100	238	164
Nitrate	200	120	210	150	171	153	167
Cyanamid	180	140	210	170	110	144	159
Phosphate	250	210	220	185	140	110	187
Bone meal	185	150	200	200	170	178	181
Waste lime	180	270	260	160	110	119	185
Composted manure	345	200	180	160	150	102	189
Dry manure	240	140	280	180	110	204	192
Manure + $(NH_4)_2SO_4$	160	160	270	340	170	229	222
Averages	219	166	223	187	137	164	

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[3] Sackett, Walter G., Patten, Andrew J., and Brown, Charles W. The Solvent Action of Soil Bacteria upon the Insoluble Phosphates of Raw Bone Meal and Natural Raw Rock Phosphate. Mich. Agr. Coll. Expt. Sta. Special Bul. No. 43, 1908.

So far as the average seasonal quantities of sulfates are concerned there was no marked effect due to the various fertilizer treatments. The plots receiving manure plus ammonium sulfate showed a higher average than the other plots. This may be accounted for, however, by the $(NH_4)_2SO_4$ applied, which amounted to 45 parts per million of SO_3, in addition to the 90 parts per million applied in the manure itself. The increased seasonal averages of sulfates in the various manured plots and in the lime and phosphate plots could easily be accounted for by the amount added in the fertilizer. The average amounts of SO_3, as given at the bottom of Table 4, indicate a general decrease from the first of June to the last of July, thus showing a behavior similar to the potash. As mentioned before, this decrease corresponds to the active growing period of the sugar beets. Other work not here reported showed the sulfur content to be closely correlated with yield as well as with sugar percentage and purity. Generally speaking, the plots showing the highest sulfur content gave the highest beet yields.

Water-Soluble Manganese.

The manganese was determined on account of the possible catalytic action of this element, and the results are shown in Table 5. It was present in such small quantities, however, that the determinations are somewhat uncertain. In general, there was a tendency for the beet yield to be directly correlated with the amount of water-soluble manganese, as was the case with the sulfates. The disappearance of the water-soluble manganese after the first week of June is of interest, but its meaning is not clear.

Table 5.—*Water-soluble manganese found on different dates in the surface foot of soil in plots variously treated, expressed in parts per million of* Mn_2O_3.

Treatment.	Dates.						Average.
	May 16.	June 3.	June 17.	July 8.	July 22.	Aug. 12.	
Nothing	0.45	0.27	0	T[a]	0	T	0.12
Nitrate	.53	.45	.36	T	0	T	.22
Cyanamid	.32	.27	0	0	0	0	.10
Phosphate	.40	.36	0	0	0	T	.13
Bone meal	.55	.36	0	0	0	T	.15
Waste lime	.78	.36	.09	T	0	T	.21
Composted manure	.45	.36	.18	T	0	T	.17
Dry manure	.44	.36	.09	T	0	T	.15
Manure + $(NH_4)_2SO_4$	.50	.27	.18	T	0	T	.16

[a] T = Trace

SUMMARY.

The plots receiving composted manure showed nearly twice as much water-soluble potash in the surface foot as any of the other plots. The seasonal averages of this element were not influenced by any other fertilizer treatment.

There was a general decrease in the quantity of water-soluble potash from the middle of May till about the middle of July. After that time, the quantity increased to approximately the amount found earlier in the season.

Plots receiving nitrate, superphosphate, and composted manure all showed less water-soluble P_2O_5 than the checks.

None of the fertilizer treatments resulted in a marked increase in water-soluble phosphates, though cyanamid, bone meal, and manure plus ammonium sulfate caused a small increase.

The variation in water-soluble phosphorus from week to week was less than that of any other element measured.

Taking account of the sulfur added in the various fertilizers, none of the treatments apparently had any marked influence in rendering the sulfates in the soil more soluble in water.

There was a decrease in the amount of soluble SO_3 from the early part of the season till the latter part of July, corresponding in general to the seasonal decrease in soluble potash.

The amounts of water-soluble manganese were very small and disappeared entirely after the middle of June.

The plots receiving nitrate, composted manure, waste lime, and manure plus ammonium sulfate, showed the highest manganese content.

It is remarked from results of the yields and other data not presented in this paper that the sugar beets grown on plots showing highest amounts of water-soluble manganese and sulfur gave the highest yields and most sugar per acre.

EXPERIMENTS IN TRANSPLANTING SUGAR BEETS.[1]

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Introduction.

One of the most expensive operations in growing sugar beets is the thinning made necessary by the use of multiple seed balls and the practice of sowing the seed rather thickly in drills to obtain a good stand. Numerous experiments in transplanting beets have been conducted in the hope of developing a method which would eliminate the labor and expense of the thinning process, but beets so handled usually either died or branched so excessively as to make them of little value.

A somewhat different method of transplanting beets than has hitherto been employed was used at Madison, Wis., during the season of 1914. The results obtained in these preliminary trials seem promising enough to justify their presentation. In previous experiments relatively small beets were used in transplanting but in our trials larger roots were employed, which were transplanted successfully after being grown in a specially prepared seed bed where they acquired a proper length and form.

In our experiments we endeavored to determine two points: (1) The relation of the length and size of the seedling at the time of transplanting to the amount and character of the branching in the mature beet, and (2) the influence of the composition of the seed bed in which seedlings intended for transplanting are grown, on their length, shape, and amount of root branching.

Size of Seedlings at Time of Transplanting.

Beets transplanted when very small usually die; if allowed to become somewhat larger, the loss from dying is mostly eliminated but excessive branching of the root often occurs. To determine whether the length and size of the seedling at the time of transplanting bear any relation to the amount and kind of subsequent branching, roots of several different lengths were used.

[1] Received for publication December 8, 1915.

THE USE OF COMPARATIVELY SHORT SEEDLINGS.

Four rows were planted with seedlings grown in a cold frame from seed sown April 14. They were transplanted to the field on May 24 when 2½ to 5 inches long and about one-fourth to one-eighth inch in diameter. The rows in which they were set alternated with rows of the variety Kleinwanzleben Original sown on May 17. A spacing of 20 inches was employed between rows and 12 inches between beets in the row. Practically every beet grew and at harvest time the yield from these rows exceeded that of those sown in the open, but many of the roots were badly branched. However, it is evident that even with such short seedlings it is possible to grow beets of fair size by transplanting.

THE USE OF COMPARATIVELY LONG SEEDLINGS.

The seedlings employed in this experiment were taken from a patch of stecklings intended for producing seed the following year. The seed was sown thickly in the row, which checked the growth of the plants and thus gave them the desired size for transplanting. The roots used varied from about one-fourth to 1 inch in diameter and were separated into three groups according to length; those in the first lot were 6 to 8 inches long, those in the second 8 to 10 inches, and those in the third 10 to 12 inches. They were planted in rows 20 inches apart on freshly prepared ground and spaced 12 inches apart in the row. Nearly every beet grew. Owing to a long period of drought, the ground remained so dry that it was impossible to transplant the roots before August 20. Hence the beets failed to reach full size during their short growing period but there was sufficient growth to determine the points desired.

The beets grown from roots 10 to 12 inches long are shown in Plate IV, fig. 1. They were dug on November 3 and represent a typical sample of the lot. It is evident that very little branching of a detrimental nature occurred. In the majority of cases most of the branching consisted of a tuft of small roots at the lower tip of the beet. As there is length enough above this point to form a good sized root, this branching has no ill effect. In some cases part of the tip had died back a short distance, but sufficient length remained to form a good beet. Such additional growth as might have been made had the beets reached full size would obviously have resulted in an increased diameter of the root the length of which was already determined. Any further tendency to branch would have been insignificant if at all manifest.

Influence of Composition of Seed Bed on Seedlings.

To determine the influence of the culture medium upon the shape of the root, a bed 14 inches deep was dug in the ground and divided into four compartments each 3½ by 6 feet in size. One was filled with common garden soil well fined, the second with a mixture of one-fourth sand and three-fourths soil, the third with a mixture of half sand and half soil, and the fourth with a mixture of three-fourths sand and one-fourth soil. Beet seed was sown rather thickly in these beds in rows about 4 inches apart. The sowing was made in the middle of the summer and, as it was difficult to keep the surface of the beds properly moistened, the germination was poor. For this reason replanting was necessary. When grown to a suitable size the roots were dug and examined. Those from the bed filled with garden soil without any mixture of sand were the shortest and most branched, while those grown in three-fourths sand and one-fourth soil were the longest, best shaped, and freest from branching. The beets from the other two beds were intermediate in these respects, but the bed composed of half sand and half soil showed a much better germination and on the whole seemed to give the best results under the conditions of dry weather which prevailed. The data indicate that it will be possible to grow roots of good shape and length for transplanting by using a proper mixture of sand in the seed bed.

General Considerations as to Planting.

Growing the Seedlings.

In order to obtain seedlings large enough for transplanting at the proper time and to protect the young seedlings from severe frost, it will be necessary to protect the seed beds with hotbed sash or plant-bed cloth. A layer of fermenting manure below the seed bed would make earlier sowing possible, and probably give the seedlings a greater tendency to grow downward towards the warm, moist layer underneath, thus increasing their length.

Proper Size of Seedlings at Time of Transplanting.

The best length of beet roots for transplanting is about 8 to 10 inches, as shown in Plate IV, fig. 2. Seedlings shorter than 8 inches are likely to produce roots rather short for commercial use, though they make fairly large beets. Those longer than 10 inches are more difficult to handle, especially if rather slender, as they are likely to double up in planting. Seedlings of such length should have a diameter of three-eighths to three-fourths of an inch. The larger the diameter the less likely the tips are to dry or break off through handling.

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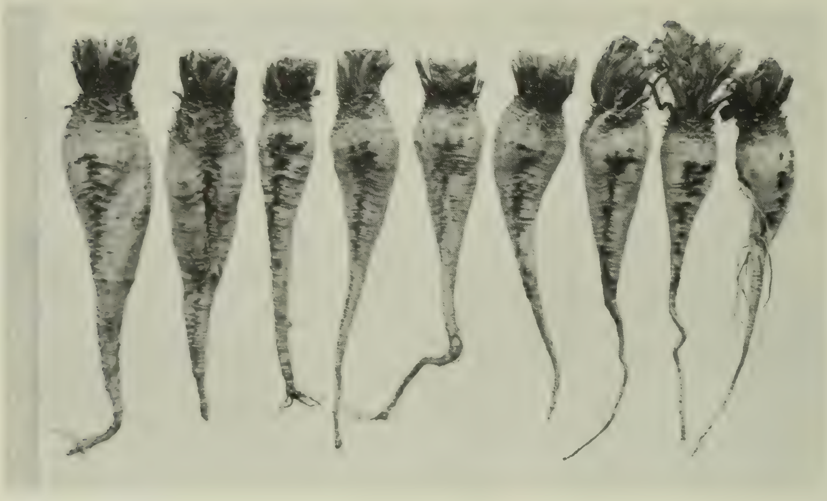

FIG. 1. Beets grown from seedlings 10 to 12 inches in length, transplanted August 20. Scale in inches.

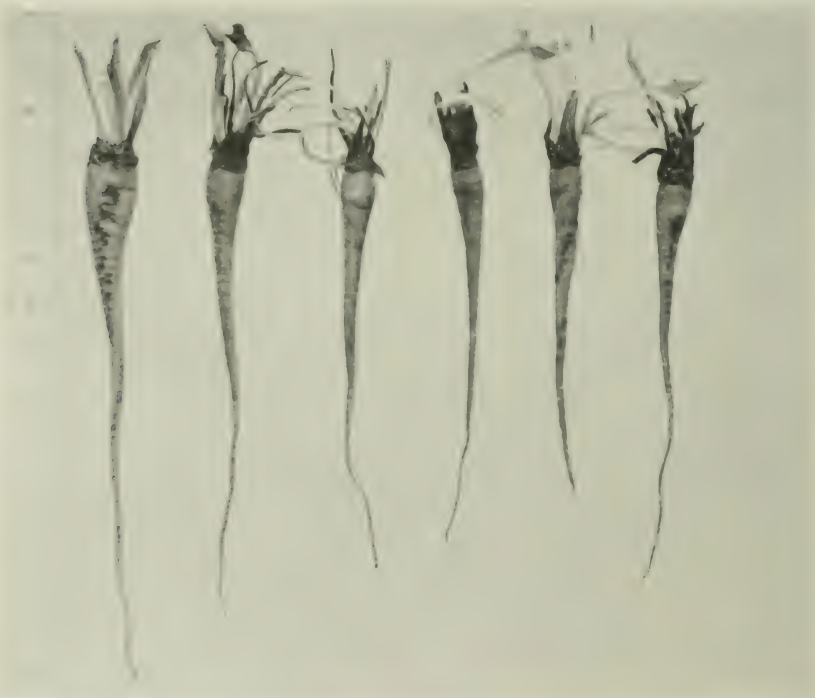

FIG. 2. Beet seedlings of desirable shape and size for transplanting. Scale in inches.

TRANSPLANTING MACHINE.

By means of a sugar-beet transplanting machine, beets may be transplanted cheaply and more uniformly than by hand. A test of the machine in setting several acres of stecklings for growing seed was very satisfactory. As the machine was originally designed for transplanting stecklings, it is provided with a shoe 12 inches deep, but it may be set for shallower depths. Two men or boys seated behind alternately set roots in the furrow while the earth is pushed and firmed against them by means of press plates and pressure wheels. In setting plants for the factory crop it may be necessary to use a little wider spacing than is commonly employed as, for instance, 2 feet between the rows and 1 foot between the beets in the row. However, transplanting at these distances should give a better average stand per acre than is obtained at present by sowing in drills.

ADVANTAGES OF THE METHOD.

One of the largest items of expense in growing sugar beets is that entailed by thinning and early hoeing. This work is performed chiefly by hired labor, as that ordinarily available on the farm is not sufficient to do it at the proper time. By transplanting the beets, thinning will be avoided and very little hoeing will be necessary, as the seedlings will be set in a freshly prepared field after they have passed their slow-growing stage and are ready to make a rapid growth. By the time the weeds appear the beets can be cultivated without danger of being covered. The transplanting can ordinarily be done by the labor on the farm, as boys are usually available who can set the roots fully as well as men.

By transplanting, it will be possible to obtain nearly a perfect stand, whereas by the ordinary method of seeding the stand is often poor and the yield correspondingly low. Not infrequently a field of beets is plowed up and replanted on account of the poor stand, which increases the cost of growing the crop and shortens the season for its production.

Where beets ripen slowly, as in the more humid sections of the country with a relatively large proportion of cloudy weather, the earlier start from transplanting may increase both yield and percentage of sugar. In other localities, it may conduce to early maturity and thus permit slicing two or three weeks sooner than is now possible, thus lengthening the campaign and increasing the capacity of the factory accordingly.

In regions where rhizoctonia and pythium cause considerable loss from the damping off of the young seedlings in the field, this method of transplanting offers a means of controlling them by sterilizing the seed bed. The improvement of the stand from this practice should raise the average yield of beets per acre.

On account of the uncertainty of obtaining a satisfactory yield of beets from the present method of sowing, many farmers are unwilling to risk $9 to $10 an acre for thinning and hoeing. Even when the farmer does the work himself, a great deal of drudgery is involved. If this drudgery can be removed by setting the fields with transplanted seedlings, beet growing should become more popular. Increasing the popularity of the sugar beet is a matter of considerable economic importance in the cooler sections of our country where there is need of more cultivated crops.

SUMMARY.

1. By transplanting fairly large sugar-beet seedlings, we obtained nearly a perfect stand of beets and very little subsequent branching of the roots occurred. Seedling roots 6 to 8 inches long made fairly good beets, although less desirable than were obtained from similar roots 8 to 12 inches in length. The latter formed a tuft of rootlets at the tip but very few undesirable branches, while their form was approximately the same as was obtained from the ordinary method of sowing.

2. Small roots 2½ to 5 inches long and one-fourth to one-eighth inch in diameter remained short and branched excessively, but on account of their earlier start grew larger than those grown from seed sown in drills and thinned by the ordinary field methods.

3. Several different proportions of sand and loam were used to determine the effect of the composition of the seed bed upon the shape of the seedling. Length of root and tendency to remain unbranched were both improved by the addition of sand to loam. The mixture consisting of three-fourths sand and one-fourth loam produced the longest, least branched, and best shaped roots, but fairly long, well shaped roots were also obtained in half sand and half loam. Roots grown in loam and in loam containing 25 percent sand were shorter and more branched.

4. These preliminary experiments show the possibilities of transplanting beets economically on a large scale, especially as the roots can be set by means of a machine. Such a method would eliminate thinning and early hoeing. It should decrease the expense of growing the crop, increase the average yield per acre, and favor an earlier maturity of the roots, while ordinarily the farmer would be able to do the work by means of the labor on the farm.

EFFECT OF QUICKLIME ON ORGANIC MATTER IN SOILS.[1]

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Considerable attention has been given in agricultural papers, in advertisements of limestone pulverizing companies, and in certain experiment station publications to the bad effect of quicklime on the organic matter in soils. The experiments of the Pennsylvania station[2] are cited to show that the use of calcium oxide is destructive to the organic matter in soils and results in an unnecessary loss of carbon and nitrogen.

The West Virginia experiment station has some evidence on this subject which is of interest in this connection. In 1890 a tract of land on the station farm was set aside for the study of the effect of fertilizers, manure, and lime. The soil is classified by the United States Bureau of Soils as Dekalb silt loam. A number of different crops have been grown on the plots, which are one-tenth acre each. A description of the soil together with a complete record of the results obtained in the field will be found in a bulletin[3] which has recently been published by the station.

This article will deal only with that part of the experiment which gives evidence on the effect of the use of quicklime. This will take into consideration plots 19, 20, 21, 22, 24, 25, 26, and 27. Table 1 gives a summary of their treatment and the yields produced as a result.

During the summer of 1915 the plots were sampled by the use of a soil auger. Thirty borings to a depth of 6⅔ inches were taken for the composite sample of soil on each plot. The samples were air dried, put through a 2-millimeter sieve to remove stones and any undecomposed pieces of organic matter and then pulverized to pass a sieve with 100 meshes to the inch.

It was thought desirable to determine the probable error in sampling

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[1] Publication authorized by the Director of the West Virginia Agricultural Experiment Station. Received for publication January 19, 1916.

[2] Hess, Enos H. Effect of Various Systems of Fertilizing upon the Humus of the Soil. Rpt. Penn. State College, 1899–1900.

[3] Bear, Firman E. Experiments with Fertilizers. W. Va. Univ. Agr. Expt. Sta. Bul. 155. 1915.

TABLE 1.—*Total pounds of produce per acre since 1900 from plots variously treated at the West Virginia station.*

Plot No.	Applications per acre since 1900.					Produce per acre since 1900.
	Nitrate of soda.	Acid phosphate.	Sulphate of potash.	Manure.	Quicklime.	
	Pounds.	*Pounds.*	*Pounds.*	*Tons.*	*Pounds.*	*Pounds.*
19	4,200	4,200	1,625	....	4,500	120,605
20	....	....	....	210	4,500	152,400
21 (check)	....	....	....	....	....	38,600
22	....	....	....	....	5,500	36,615
24 (check)	....	....	....	....	....	43,075
25	....	....	....	190	....	139,670
26	4,200	4,200	1,625	....	....	117,910
27 (check)	....	....	....	....	....	42,170

a plot. Accordingly, six composite samples of 30 borings each were chosen from plot 26 and prepared for analysis. The determinations of total carbon, nitrogen, and phosphorus are given in Table 2.

TABLE 2.—*Percentages of carbon, nitrogen, and phosphorus in a soil as determined by duplicate analyses of 6 composite samples from the same plot.*

Sample.	Total carbon.		Total nitrogen.		Total phosphorus.	
	Analysis A.	Analysis B.	Analysis A.	Analysis B.	Analysis A.	Analysis B.
1	1.527	1.505	0.1295	0.1292	0.0452	0.0447
2	1.547	1.562	.1379	.1375	.0472	.0455
3	1.507	1.493	.1337	.1333	.0460	.0457
4	1.522	1.543	.1325	.1325	.0447	.0450
5	1.637	1.644	.1477	.1473	.0477	.0485
6	1.518	1.518	.1351	.1351	.0452	.0460

It will be seen from Table 2 that there is a very close agreement among five of the six samples. No explanation is available for the differences to be noticed in sample 5. However, these differences necessitate a more careful study of the results to follow in order to be certain that the figures prove the point at issue.

The results of the analyses of the various plots under consideration figured on the basis of 2,000,000 pounds of soil to an acre 6⅔ inches are given in Table 3.

In every case the plot receiving quicklime, as compared to the plot receiving a corresponding fertilizer application without quicklime, shows a lower content of both nitrogen and carbon. Since there are no exceptions to this general statement it seems improbable that errors in sampling would account for the differences. The results indicate that quicklime does reduce the amount of carbon and nitrogen in the soil. This loss would not be serious if there were a sufficient increase in yield to justify it.

TABLE 3.—*Total carbon and total nitrogen in soil variously treated, expressed in pounds per acre in 2,000,000 pounds of surface soil.*

Plot No.	Treatment.	Total carbon (pounds per acre).	Total nitrogen (pounds per acre).
19	Lime and fertilizer	24,480	2,128
20	Lime and manure	32,490	2,695
21	Check	21,150	1,833
22	Lime	19,380	1,750
24	Check	20,760	2,035
25	Manure	36,880	3,234
26	Fertilizer	30,890	2,733
27	Check	21,910	1,953

Determinations of the present lime requirement of the plots by the Veitch method show that quicklime was used in excess of the needs of the surface soil. The average lime requirement of the check plots is 3,500 pounds of calcium carbonate per acre to a depth of 6⅔ inches. The plots which have received an application of fertilizer and lime and of manure and lime, i. e., 19, 20, and 22, show negative lime requirements. The lime requirements of the subsoil in the 3 plots receiving lime averages 3,400 pounds of $CaCo_3$ per 4,000,000 pounds of subsoil. No data are available on the effect of ground limestone or on smaller applications of quicklime.

These data are not presented as an argument against the use of quicklime, but simply as a statement of the facts as shown by analysis.

GROWING PLANTS IN LARGE CONTAINERS UNDER CONTROL CONDITIONS.[1]

R. CLAUDE WRIGHT,

BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE.

In the course of a soil bacteriological study carried on by this laboratory it became necessary to grow certain plants under control conditions and yet have them under as near natural conditions as possible. The method used seems of sufficient merit to describe briefly. The soil containers are heavy corrugated galvanized iron buckets or cans 15 inches in diameter by 13 inches deep. Three ⅜-inch holes in the bottoms provide drainage and aeration. The cans hold about 100 pounds of soil, a reasonably large quantity, yet

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[1] Contribution from the Laboratory of Soil Bacteriology, U. S. Department of Agriculture. Received for publication December 6, 1915.

not too heavy to be handled readily. These cans are placed in wells made by sinking 18-inch terra cotta sewer tiles to within 2 inches of the surface of the ground. Each can is supported on bricks so that the top of the can is flush with the edge of the tile. Two-quart granite pans to catch any drainage are placed in the wells beneath the cans. After planting, the cans are watered to weight daily with distilled water. To facilitate the weighing and watering, the cans are arranged in rows over which runs a light derrick built of 1-inch pipe mounted on broad tread trucks. This derrick supports a lifting tackle consisting of a double block and fall, and also a spring dial balance which when lowered hooks into the bails of the cans. (See Plate V.)

Over all is a cage house, 20 by 40 feet in size, 7 feet high at the sides and 11 feet through the center, built of 1-inch galvanized iron pipe and covered with ¼-inch mesh galvanized wire netting as a protection against hail storms and birds. Excess rain is shed by a light galvanized iron lid for each pot with 10 holes ⅞-inch in diameter through which the plants grow.

To determine how nearly natural conditions of temperature were approximated, daily minimum and maximum temperatures of the air at the surface of the ground, of the soil in a can in a well, of the soil in a can resting on the surface of the ground, and of the surrounding natural soil were recorded daily for two weeks. The temperature records of the air, of natural soil, and of soil in a can in a well are given in Table 1 and figure 4.

TABLE 1.—*Daily minimum and maximum temperatures in degrees F. of the air, of natural soil, and of soil in a can in a well, as recorded during a 2-week period.*

FIRST WEEK.

Location of thermometer.	Tuesday.	Wednesday.		Thursday.		Friday.		Saturday.		Sunday.		Average.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Air	94	70	92	75	83	73	99	72	99	75	98	73	94
Natural soil	78	73	78	75	76	74	81	75	82	76	82	75	79
Can in well	80	71	79	73	75	73	83	73	87	76	87	73	82

SECOND WEEK.

Air	81	68	84	58	92	60	90	71	83	70	96	65	88
Natural soil	78	71	77	70	78	70	78	74	77	75	82	72	78
Can in well	76	64	73	63	75	62	74	70	75	72	80	66	75

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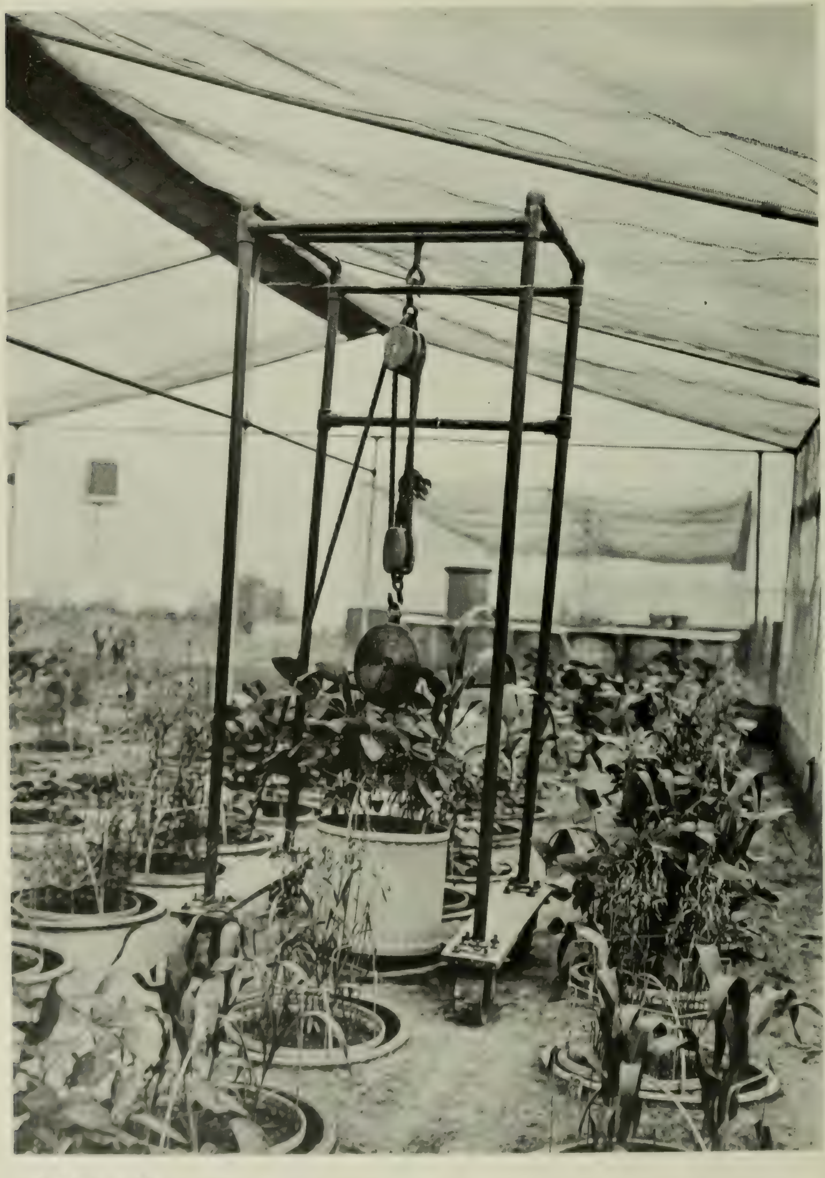

Interior of cage house, showing cans set in tile wells and apparatus for weighing.

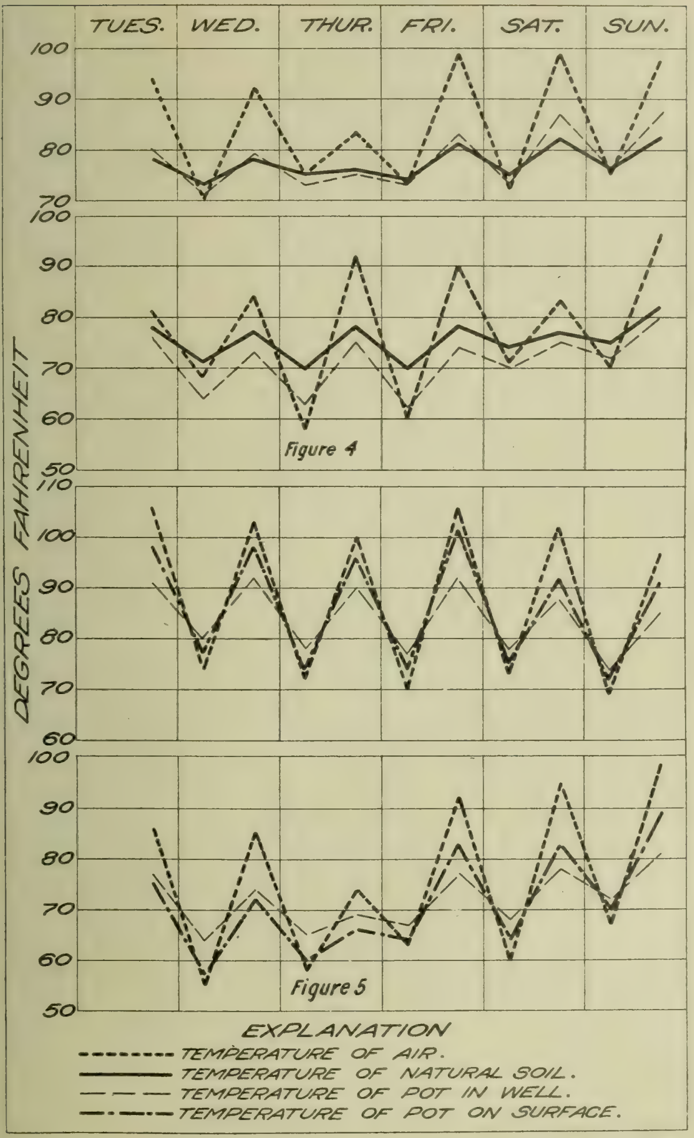

FIG. 4. Upper portion, graph showing daily temperatures of the air, of natural soil, and of soil in a can in a well during the first week of the experiment; lower portion, temperatures during second week (Table 1).

FIG. 5. Upper portion, graph showing daily temperatures of the air, of soil in a can in a well, and of soil in a can on the surface during the first week of the experiment; lower portion, temperatures during the second week (Table 2).

Table 1 shows that in general the temperature of a can in a well fairly approaches that of the natural soil except that when rather cold nights occurred during the second week the temperatures of the can were lower.

The maximum and minimum temperatures of the air, of soil in a can in a well, and of soil in an unprotected can on the surface of the ground are given in Table 2.

TABLE 2.—*Daily minimum and maximum temperatures in degrees F. of the air, of soil in a can in a well, and of soil in a can on the surface, as recorded during a 2-week period.*

FIRST WEEK.

Location of thermometer.	Tuesday.	Wednesday.		Thursday.		Friday.		Saturday.		Sunday.		Average.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Air	106	74	103	72	100	70	106	73	102	69	97	72	102
Can in well	91	80	92	78	90	77	92	78	88	74	85	77	90
Can on surface	98	77	98	74	96	74	101	75	92	72	91	74	96
SECOND WEEK.													
Air	86	55	85	58	74	63	92	60	95	67	99	61	88
Can in well	77	64	74	65	69	67	77	68	78	72	81	67	76
Can on surface	75	57	72	60	66	64	83	64	83	70	89	63	78

Table 2 and figure 5 show that the extremes of the air temperature were followed much more closely by the temperature of the unprotected can, the protected can remaining cooler during the day and warmer at night.

The advantages of the tile wells may be concluded as follows: (1) They are durable; (2) they allow the cans to be lifted out readily and replaced; and (3) they keep the temperature of the cans more uniform and nearer that of the natural soil, preventing excessively high temperatures during the heat of the day when cans on the surface exposed to the sun become very warm, especially near the sides.

VARIATIONS IN NODULE FORMATION.[1]

LEWIS T. LEONARD,

BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE.

The production of nodules upon the roots of a leguminous plant is dependent mainly on the concentration and virulence of the organisms

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[1] Received for publication November 17, 1915.

symbiotic with the legume in the surrounding soil, the physical and chemical condition of the soil, and apparently the susceptibility of the plant to inoculation. Varying degrees of susceptibility to inoculation have been noticed within varieties as well as between varieties of legumes, the latter principally in connection with the soy bean.

Observations on plots of legumes at the Arlington Farm, Rosslyn, Va., laboratory culture tests, and reports of farmers cooperating with the Department of Agriculture have shown striking differences in the intensity of the inoculation on the roots of plants of the same variety from the same lot of seed. Instances of plants growing side by side have been noticed on numerous occasions where one plant would be excellently inoculated while the other would be practically free from nodules. This condition may be due to an extremely localized distribution of the organisms, but evidence seems to favor the individual resistance of the plant as an explanation. Whiting[2] attributes this immunity to physical and antagonistic biological factors. Differences in susceptibility to inoculation between varieties of soy beans, and even in some instances apparent total resistance to inoculation, have been noted by Kellerman and Robinson[3], Voorhees,[4] and Morse.[5] All of these observations have been made in the field.

In 1914 the question of the possibility of the use of one soy bean pure culture for the inoculation of all varieties of soy beans was taken up. This experiment was carried out under controlled laboratory and greenhouse conditions. Jars such as those described by Kellerman[6] were used, the plants being grown in Dunkirk gravelly loam from Ithaca, N. Y. The soil was placed in the jars and moistened with distilled water. The jars were then closed and sterilized under steam pressure at 20 pounds for one hour. The pure culture used in this experiment was isolated in May, 1913, from nodules of the Medium Yellow soy bean plant.

The seeds of 19 varieties of soy beans were sterilized with a solution of mercuric chlorid, washed in sterile water, and planted in the special jars. At the time when growth was first perceptible 1 cubic centimeter of a broth culture of the soy bean organism was introduced into each of two jars of each variety of the soy beans. An untreated set of two jars for each variety was put aside as control. All jars were then kept in a well-shaded greenhouse for a time. At the conclusion of the test, the plants were washed from the jars and the roots examined for nodules. The results of these tests were as follows:

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[2] Whiting, Albert L. A Biochemical Study of Nitrogen in Certain Legumes. Univ. Ill. Agr. Expt. Sta. Bul. No. 179. 1915.

[3] Kellerman, K. F., and Robinson, T. R. Conditions Affecting Legume Inoculation. U. S. Dept. Agr., Bur. Plant Indus. Bul. No. 100, part VIII, p. 11. 1907.

[4] Voorhees, John H., Variations in Soy Bean Inoculation. JOUR. AMER. SOC. AGRON., vol. 7, no. 3, p. 139. 1915.

[5] Morse, W. J. JOUR. AMER. SOC. AGRON., vol. 7, no. 3, p. 140. 1915.

[6] Kellerman, K. F. Testing Cultures of Nodule-Forming Bacteria. *In* Miscellaneous Papers, U. S. Dept. Agr., Bur. Plant Indus. Circ. 120. 1913.

Variety.	Duration of experiment, days.	Number of jars showing inoculation.
Amherst	98	1
Arlington	85	2
Auburn	85	2
Barchet	85	2
Chernie	85	0
Chestnut	98	2
Cloud	85	1
Guelph	98	2
Haberlandt	98	2
Hope	98	2
Ito San	98	2
Jet	85	2
Manhattan	98	2
Medium Yellow	98	2
Peking	85	2
Taha	85	2
Tokio	98	2
Virginia	98	2
Wilson	85	1

The first two tests made on Chernie soy beans produced no results. The plants were in very poor condition at the time the examinations were made. On the third trial with this variety, sparse nodule formation occurred in 61 days. At the same time the test was being conducted with Chernie soy beans, plants of the Sable soy bean were treated with the culture used in the original series; nodules were produced in 61 days.

From the results obtained in the above experiment and from the reports of the successful use of this soy bean culture and cultures from other varieties of soy bean in many field trials it is evident that a soy bean culture isolated from a single strain of soy beans will successfully inoculate any of the varieties noted above.

AGRONOMIC AFFAIRS.

CHANGES IN STANDING COMMITTEES.

The standing committees of the Society are five in number. They include (1) the Executive Committee and Committees on (2) Agronomic Terminology, (3) Soil Classification and Mapping, (4) Standardization of Field Experiments, and (5) Varietal Nomenclature. The personnel of the Executive Committee usually changes with the annual election. There has been little change in the membership of the other committees for several years.

At the annual meeting held in Berkeley, Cal., last August, a reduction in the size of the Committee on Soil Classification and Mapping was suggested by its chairman. On motion the matter was referred to the Executive Committee with power to act. The Executive Committee has voted to reduce the size of this committee from fifteen to five members. The new committee of five has been formed, with Prof. C. F. Marbut, of the Bureau of Soils, as chairman. Dr. Geo. N. Coffey had been chairman of the committee of fifteen since it was first elected. The change in chairman was made at his urgent request, as he believed that some one now actively engaged in soil surveys should head the committee. He felt further that the chairman should be a member of the United States Bureau of Soils, since it is the largest single organization engaged in this work.

Some changes in the membership of the other committees also seem desirable. The complete reorganization of the Committee on Soil Classification and Mapping offered occasion for making them. All changes have been made with the object of bringing into service men not only interested, but more or less actively engaged in the lines of investigation covered. In this process it has seemed proper for your President to remove himself from the chairmanship of the Committee on Agronomic Terminology. This chairmanship is assumed by Prof. C. V. Piper, the writer remaining a member of the committee.

Members of the Society are invited to study the personnel of these new committees. They are urged further to send to the committee chairman or members any suggestions concerning the subjects covered. Let us all work together to make each succeeding year the best in the history of our Society. We are now enjoying an unprecedented growth, for 131 new members have been added to the Society since the last annual meeting. Let each member feel personally responsible for making more clear some of the fundamental principles and practices in agronomy. The year 1916 is before us. Let us make it a banner year of progress along all lines.—C. R. B.

THE SECOND PAN-AMERICAN SCIENTIFIC CONGRESS.

The Second Pan-American Scientific Congress, which met in Washington, D. C., December 27, 1915 to January 8, 1916, was in many respects a notable gathering. Perhaps the feature that occasioned most remark was the fact that, while the great nations of the Old World were at war, official delegates from twenty-one republics of the New World were meeting in friendly council to discuss questions of science and education. The congress was broad in its scope, a breadth perhaps accounted for by the fact that the Spanish word "cientifico" includes much that does not come within the English "scientific." Matters of politics and commerce as well as of science and education were discussed during the sessions.

As a matter of fact, the political features of the congress overshadowed the scientific. Secretary of State Lansing made one of the sessions the occasion for an informal proposal to the nations of the Pan-American Union that they join in a treaty for the settlement of all disputes by arbitration and embracing other features calculated to promote peace throughout the New World. President Wilson, in his address to the congress, urged a closer bond between Latin America and the United States. Many citizens of the United States prominent in the fields of politics and diplomacy, as well as the diplomats from the South and Central American nations, took part in the discussions.

While matters of politics were perhaps dominant, scientific topics of importance and variety were discussed by many of the leaders of thought in both North and South America. A comparatively small place on the program was given to agriculture and the related sciences, though these were well recognized in the resolutions adopted at the close of the congress. An important topic of discussion was the need of a medium for the interchange of agricultural plants and for a Pan-American plant quarantine. Another topic in which much interest was shown was the use and conservation of water for irrigation and the reclamation of arid lands.

As was to be expected, the social side of the congress loomed large.

In addition to many private receptions, the delegates were received on different occasions by the official delegates from the United States, by the trustees of the Smithsonian Institution, by the officials of the Pan-American Union, by the Cosmos Club, by the trustees of the Carnegie Institution of Washington, and, lastly, by the President of the United States at the White House.

Among the important resolutions adopted by the congress were those urging the appointment of a commission to study laws and regulations regarding the use of water for power and irrigation; suggesting a careful study of the possibilities for reclaiming arid lands; outlining a national and an international livestock quarantine service; planning an American plant-protection conference; and recommending the distribution of information on agricultural production in the different countries.

MEMBERSHIP DUES FOR 1916.

The annual dues of members, according to the constitution of the Society, "shall be paid on or before April 1 of the year for which membership is held." The fee for 1916 is therefore now due and payable to the treasurer. Members are urged to remit promptly in order to lessen the work of that official in sending out notices and also to save expense to the Society. They are requested to note that applications for membership, with the accompanying dues, and remittances for back volumes of the Society's publications are to be sent to the secretary, but that the dues of all members should be sent to the treasurer.

Those whose dues for 1915 still remain unpaid lapsed automatically on April 1, and their names will be published in the May–June number of the JOURNAL. By paying their dues for 1915, these lapsed members still have opportunity to be reinstated. Those whose dues are paid before May 15 will not be included in the published list.

ERRATA IN THE JANUARY–FEBRUARY NUMBER.

The following corrections should be made in the January–February number of the JOURNAL:

Page 36, line 3 in Table 5, for "3.362" read "33.62."

Page 43, line 34, for "that plan" read "the plan."

Page 49, line 35, for "029" read "0.29."

Page 55, line 5 in Table 1, for "97.90" read "147.90" and for "97.9" read "98.6."

MEMBERSHIP CHANGES.

The membership reported in the January–February JOURNAL was 516. Since that time, 2 members have resigned and 52 new members have been added, making a net gain of 50, the largest increase in membership yet recorded for a similar period. The number of new members for 1916 so far recorded is 97, only 10 less than the total number added in 1915. The total membership of the Society at this date is 566. The names of the new members, those who have resigned, and those whose addresses have been changed recently, are as follows:

NEW MEMBERS.

BAUER, F. C., 715 South Prairie St., Champaign, Ill.
BENNETT, CHARLES D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
BLISS, S. W., 420 Fourteenth Avenue, Columbus, Ohio.
BOYACK, BREEZE, Experiment Station, Fort Collins, Colo.
BREITHAUPT, L. R., Harney Branch Station, Burns, Oreg.
BURLISON, W. L., Room 607D, Agr. Bldg., Univ. of Ill., Urbana, Ill.
DAVIDSON, JEHIEL, Bur. Chemistry, U. S. Dept. Agr., Washington, D. C.
EDWARDS, R. W., Experiment Farm, Chillicothe, Texas.
ELLIS, ORLAND I., 654 Agr. Bldg., Univ. of Ill., Urbana, Ill.
EWAN, A. E., Greenville, Ky.
FLORELL, VICTOR H., Cheyenne Expt. Farm, Archer, Wyo.
FREEMAN, GEORGE F., Experiment Station, Tucson, Ariz.
GAUCH, RAYMOND C., 183 West Ninth Avenue, Columbus, Ohio.
GRAVES, GEORGE W., 718 Elm St., Moscow, Idaho.
HEADLEY, F. B., Truckee-Carson Field Station, Fallon, Nev.
HELM, C. A., State Farm, Lincoln, Nebr.
HOLBERT, J. R., Funk Bros. Seed Co., Bloomington, Ill.
HORTON, HORACE E., Amer. Steel & Wire Co., 208 LaSalle St., Chicago, Ill.
JENNINGS, D. S., Dept. of Soils, Cornell University, Ithaca, N. Y.
JENSEN, CHARLES A., 1035 West Ninth St., Riverside, Cal.
KARPER, R. E., Lubbock Substation, Lubbock, Texas.
KYLE, C. H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
LAPHAM, MACY H., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
LEDYARD, EDGAR M., Agr. Dept., U. S. Smelting Co., Salt Lake City, Utah.
LEITH, B. D., Agronomy Bldg., University of Wisconsin, Madison, Wis.
LEONARD, LEWIS T., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
LINTNER, W. A., Experiment Station, Newark, Del.
McCLYMONDS, A. E., State Agr. College, Manhattan, Kans.
McMILLER, P. R., University Farm, St. Paul, Minn.
MARTIN, THOMAS L., Dept. Soil Tech., Cornell Univ., Ithaca, N. Y.
MOORE, HARVEY L., Leonard Apts., Bellevue and Prospects Sts., Trenton, N. J.
MORGAN, O. S., Columbia University, New York, N. Y.
NUCKOLS, SAMUEL B., Sugar Beet Inv., Fort Collins, Colo.
OGAARD, A. J., Hettinger Substation, Hettinger, N. Dak.
OSBORN, W. M., Lawton Experiment Farm, Lawton, Okla.
PARKER, J. H., 214 Thurston Ave., Ithaca, N. Y.

Pendleton, Robert L., 2342 Eunice St., Berkeley, Cal.
Petry, Edward J., 267 Wood St., West La Fayette, Ind.
Rose, C. M., Ohio State University, Columbus, Ohio.
Rost, C. O., University Farm, St. Paul, Minn.
Ruzicka, C. H., Williston Substation, Williston, N. Dak.
Sarvis, J. T., Northern Great Plains Field Station, Mandan, N. Dak.
Severance, George, 1403 Star Route, Pullman, Wash.
Sherbakoff, C. D., College of Agr., Gainesville, Fla.
Snyder, Robert M., 214 Thurston Ave., Ithaca, N. Y.
Stanley, Clarence W., 210 Waldron St., La Fayette, Ind.
Stephens, David E., Eastern Oreg. Dry-Farming Substa., Moro, Oreg.
Stookey, E. B., West Washington Expt. Farm, Puyallup, Wash.
Vivian, Alfred, Ohio State University, Columbus, Ohio.
Waller, Allen J., Agronomy Dept., Expt. Sta., New Brunswick, N. J.
Walworth, E. H., Agr. Experiment Station, Urbana, Ill.
Young, Horace J., University Farm, Lincoln, Nebr.

Members Resigned.

McFetridge, William L.
Neff, C. E.

Addresses Changed.

Evans, M. W., 907 Middle Avenue, Elyria, Ohio.
Galbraith, A. J., Manitoba Agr. College, Winnipeg, Manitoba.
Hershberger, Jos. P., jr., County Agent, Hillsboro, Ohio.
Humbert, Eugene P., Agr. Experiment Station, College Station, Tex.
La Tourrette, Lyman D., R. F. D. No. 1, Phoenix, Ariz.
Mosher, M. L., Woodford County Farm Bureau, Eureka, Ill.
Woodard, John, Ontario Agr. College, Guelph, Ontario.

NOTES AND NEWS.

C. H. Bailey, cereal technologist at the Minnesota station, delivered a course of lectures accompanied by laboratory demonstrations on "Methods of Evaluation of Wheat and Flour" at the short course for bakers held under the auspices of the Department of Home Economics at the University of Illinois during the last week in January.

W. E. Bryan, assistant in agronomy at the Louisiana station, has been appointed assistant plant breeder at the Arizona station.

T. W. Buell, who has been superintendent of the Denton (Texas) substation, has resigned to engage in farming. He has been succeeded by V. L. Cory, who has been superintendent of the substation at Lubbock, Tex. R. E. Karper, formerly assistant agronomist of the Oklahoma college and station, is now in charge of the Lubbock substation.

Frank K. Cameron, until recently chemist of the Federal Bureau of Soils, delivered one of the three public lectures complimentary to the citizens of Columbus, Ohio, in connection with the recent meeting there of the American Association for the Advancement of Science. His subject was "The Fertilizer Resources of the United States."

R. J. Davidson, for the past 25 years professor of chemistry at the Virginia Polytechnic Institute, died suddenly on December 19. In recent years, Professor Davidson has been dean of the scientific department of the college.

F. W. Duffee has been appointed instructor in agronomy in the Connecticut college of agriculture.

R. H. Forbes, director of the Arizona station, has been given a year's leave of absence for study at the Graduate School of Tropical Agriculture at Riverside, Cal. During his absence, G. F. Freeman, head of the department of plant breeding, will be acting dean and director.

P. L. Gaddis is now assistant professor of agronomy and R. E. Holland is assistant in instructional agronomy in the University of Nebraska.

W. J. Geib, formerly connected with the soil survey of the U. S. Bureau of Soils, has been appointed assistant professor of soils in the University of Wisconsin.

Oliver Gossard and O. H. Smith are recent appointees in soil investigations at the Ohio station.

F. S. Grisdale is now principal of the school of agriculture at Vermilion, Alta., having succeeded E. A. Howes.

T. J. Harrison, for a number of years superintendent of the substation at Indian Head, Sask., has been appointed professor of field husbandry in the Manitoba Agricultural College. He has been succeeded at Indian Head by W. H. Gibson, formerly assistant superintendent of the substation at Lacombe, Alta.

E. W. Hilgard, professor of agriculture in the University of California for thirty years (1875-1904), died on January 8 at the age of 84. Dr. Hilgard was distinguished for his work in agricultural chemistry, geology, and soils, and was the author of several excellent books on these subjects.

E. A. Howes, formerly principal of the school of agriculture at

Vermilion, Alta., is now dean of the faculty of agriculture in the newly established college of agriculture at the University of Alberta. George A. Harcourt, deputy minister of agriculture for Alberta, is assistant to the dean.

Leonard Hegnauer is now soils and crops specialist in field work for the extension department of the Washington college.

E. P. Humbert, agronomist of the New Mexico college and station for several years and dean of the college of agriculture since July 1, resigned January 1 to take charge of inheritance studies at the Texas station.

H. H. Jobson, assistant agronomist of the Texas station, has leave of absence for two years from November 1, 1915, to serve as cotton expert for the Chinese government.

A. E. McClymonds and J. W. Zahnley are now instructors in agronomy at the Kansas college. Mr. McClymonds is also superintendent of the agronomy farm.

C. E. Miller, formerly instructor in soils in the Kansas college, is now assistant professor of soils in the Michigan Agricultural College.

M. L. Mosher, for the past three years county agent in Clinton Co., Iowa, on January 1 became county agent in Woodford Co., Illinois, with headquarters at Eureka.

J. F. Nicholson, formerly bacteriologist of the Idaho college and station, became agronomist of the Arizona station on January 1.

Robert M. Salter has been appointed assistant in soils in the West Virginia college and station, succeeding J. H. B. Krak, who becomes assistant chemist.

M. C. Sewell, superintendent of the Garden City (Kans.) substation, has been appointed assistant professor of soils in the Kansas college and station.

J. B. Thompson, formerly in charge of the experiment station on the Island of Guam, is now assistant agronomist in charge of the Glenwood (Hawaii) substation.

Allen G. Waller is a recent appointee as assistant in crops in the New Jersey college and station.

L. R. Waldron, who has been superintendent of the Dickinson (N. Dak.), substation practically since its establishment in 1905, on March 1 assumed charge of the crop breeding work of the North

Dakota station at Agricultural College. He has been succeeded at Dickinson by John C. Thysell, who has represented the Federal Office of Dry-Land Agriculture there for several years.

Henry Wallace, one of the best known agricultural writers in America and for the past 21 years editor and publisher of *Wallace's Farmer,* died at Des Moines, Iowa, on February 22.

F. M. Webster, for the past ten years in charge of the section of cereal and forage insect investigations in the U. S. Bureau of Entomology, died of pneumonia January 3 at Columbus, Ohio, where he had been attending the meeting of the American Association for the Advancement of Science. Before entering the government service in 1904, he was for twelve years entomologist of the Ohio station. Professor Webster was one of the best known entomologists in the United States, having been engaged in entomological work for more than forty years.

Charles R. Weeks, professor of agriculture in the Winthrop Normal and Industrial College, at Rockhill, S. C., became superintendent of the Fort Hays Branch Experiment Station, Hays, Kans., on March 15, *vice* G. K. Helder, resigned to engage in commercial work.

John A. Widtsoe, president of the Utah Agricultural College since 1907, has been elected president of the University of Utah. He will assume his new duties some time between July 1 and September 1, 1916. E. G. Peterson, for several years director of the agricultural extension division of the Utah college, has been elected to succeed him.

John Woodard, formerly assistant in soil survey at the Ohio station, was engaged in graduate study at Johns Hopkins University from September to January. On January 1 he assumed charge of the field work of the Ontario soil survey, with headquarters at Guelph. He will complete the reconnoissance survey of Ontario begun last summer by G. N. Coffey and A. J. Galbraith.

J. H. Worst, for the past 21 years president of the North Dakota Agricultural College and director of the experiment station for the greater part of that time, was succeeded as president on March 1, by E. F. Ladd. Dr. Ladd has been chemist of the North Dakota college and station for many years.

Announcement has been made of the seventh biennial session of the Graduate School of Agriculture under the auspices of the Association of American Agricultural Colleges and Experiment Stations, which will be held at the Massachusetts Agricultural College July 3 to 28, 1916. The courses to receive special attention are: (1) Factors of growth of plants and animals; (2) fundamental problems of intensive agriculture, including agronomy, horticulture, and dairy husbandry; and (3) agricultural economics and rural sociology. Each course consists of 20 lectures and 20 seminars.

The annual meeting of the American Association for the Advancement of Science was held at Columbus, Ohio, December 27, 1915 to January 1, 1916. About 900 men and women were in attendance at the sessions. C. R. Van Hise, president of the University of Wisconsin, was elected president of the association for 1916. G. H. Parker of Harvard University was elected vice-president of Section F, zoology; T. J. Burrill of the University of Illinois, vice-president of Section G, botany; and W. H. Jordan, director of the New York State Experiment Station at Geneva, vice-president of Section M, agriculture. The next meeting of the association will be held in New York, December 26 to 30, 1916.

Local Sections.

Meeting of the New England Section.

The agronomists of the New England States met in Boston, December 11, 1915, and organized as the New England section of the American Society of Agronomy. W. L. Slate, jr., of Connecticut, was elected president; Earl Jones, of Massachusetts, secretary and treasurer; and George E. Simmons, Maine, member of the executive committee. F. W. Taylor, of New Hampshire, read a paper on "Fertilizers for 1916, with Special Reference to the Potash Situation." F. S. Prince, of New Hampshire, discussed some experimental work on the inoculation of soy beans at the New Hampshire station, and B. G. Southwick, of Connecticut, read a paper on the corn survey work of the Connecticut college. The section assumed charge of the field crops judging contest of the New England agricultural colleges, which has formerly been under student management, and will present a cup to the winning team. After discussion of a potato score card, it was voted to construct, if possible, a uniform score card to be used by all the New England colleges.

Meetings of the Washington Section.

The tenth regular meeting of the Washington (D. C.) section was held at the Cosmos Club on December 17, 1915.

A. C. Dillman presented a paper entitled "The Seasonal Water Requirement of Alfalfa," in which it was shown that the water requirement of this crop varies greatly with the character of the growing season, being high in hot, dry seasons and low in cool, moist ones. It also varies with the time of the year, ordinarily being lower for the first cutting than for later ones. The water requirement of the yellow-flowered alfalfa, *Medicago falcata,* was shown to be lower for the first and higher for the third crop than that of the common alfalfa.

H. K. Dean, in his paper on the "Relation of Soil Moisture to the Sandy Soils of the Columbia River Valley," stated that the moisture problem on the sandy soils of the Columbia River Valley is very important because of their low water-holding capacity and their open texture, which permits rapid percolation. On the Umatilla Project the loss from percolation is so great that serious difficulties are encountered in getting the water properly distributed. Percolation experiments have been conducted which show that this soil will not take up more than 2.5 acre-inches of water. It has, however, been found impossible to get an application of less than 3 or 4 acre-inches over the soil, even with an elaborate distribution system.

Lyman Carrier, in his talk on "The History of Blue Grass and White Clover in the United States," discussed all the available references to these plants by the early explorers. The evidence indicates that along the Atlantic coast both were introduced species. The first white men to travel through Kentucky and Ohio found blue grass and white clover growing in large areas. If in that region they are introduced plants, the rapidity with which they had spread without the aid of the white man is of special interest.

The eleventh regular meeting of the Washington (D. C.) section was held at the Cosmos Club, January 18, 1916. Roland McKee presented an illustrated paper entitled "The Use of Samples in Correcting Forage Yields." In this paper Mr. McKee discussed the inaccuracy of forage yields as ordinarily recorded, and presented data to show that the most satisfactory method yet devised was to record the green weight of the forage when cut and then determine its water-free weight by means of representative samples dried to constant weight. A considerable part of the paper was devoted to the discussion of experiments conducted to determine the size of sample and number of replications which gave most accurate results with various forage crops.

"Moisture Penetration in the Gumbo Soils of the Belle Fourche Project" was discussed by O. R. Matthews. This soil shows a remarkable expansion when wet which practically prevents the passage of water through it. In a dry soil, water penetrates rapidly through the numerous cracks to a depth of about two feet, when further penetration is cut off by the swelling of the surface soil. In a wet soil, the movement of water is so slow that it can scarcely be detected.

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THE ROOT SYSTEMS OF AGRICULTURAL PLANTS.[1]

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In his investigations of the roots of corn and sorghum, the author had occasion to review the literature on the growth and development of the root systems of agricultural plants in general. This review included (1) the extent of root systems, including methods for their isolation; (2) the relation of the weight of roots to the aerial portion of the plant; and (3) the influence of moisture, fertilizers, and oxygen on root growth and development.

Since a summation of the work that has been done along these lines would be of value both to the teacher and to the investigator in agronomy, it was thought best to publish a more thorough review of the literature than could possibly be given in the ordinary introduction to a research article. The literature here quoted has all been read in the original with the exception of the few articles so indicated in the bibliography. The tables given have for the most part been abstracted and rearranged and many new calculations made in order to bring out what seemed to be the most important facts.

Hales (1727)[2] examined the root system of a sunflower 3.5 feet in height. He measured and weighed a portion of one of the main roots with its laterals. All the main roots with their laterals were then weighed and from these figures he estimated that the total length of all the roots was 1,448 feet.

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[1] A review of the literature on the root systems of agricultural plants. Received for publication January 12, 1916.

[2] Names and dates refer to papers similarly designated in the bibliography at the end of this paper.

Schubart (1855) studied winter wheat, rye, rape, and clover at two stages of their growth in regard to the depth of their root development and the ratio of the weight of the stem and leaves to the weight of the root systems. He dug a trench 5 to 6 feet deep and then washed the perpendicular walls with water until the roots were laid bare. His observations are summarized in Tables 1 and 2.

TABLE 1.—*Length of roots of winter wheat, winter rye, winter rape, and clover, as determined by Schubart.*

Plant.	Date sown.	Date taken up.	Length of roots.	Date taken up.	Length of roots.
Winter wheat	Sept. 26	Apr. 30	3 ft., 2 in.	June 14	3 ft., 11 in.
Winter rye	Sept. 16	Apr. 29	3 ft., 9 in.	June 13	3 ft., 9½ in.
Winter rape	Aug. 1	Apr. 30	3 ft., 10 in.	June 7	4 ft., 2 in.
Clover, 1 year old	———	Apr. 2	3 ft., 6 in.		
Clover, 2 years old	———	Apr. 2	3 ft., 11 in.		

TABLE 2.—*Dry weight of stems, leaves, and roots of wheat, rye, rape, and clover, as determined by Schubart.*

Plant.	Date sown.	Date taken up.	Weight of stems and leaves.	Weight of roots.	Ratio of weight of stems and leaves to weight of roots.
			Grams	*Grams*	
Winter wheat	Sept. 26	Apr. 30	0.232	0.154	1.5:1
Do.	Oct. 26	June 8	1.372	.374	3.7:1
Winter rye	Sept. 16	Apr. 29	.126	.64	2.0:1
Winter rape	Aug. 1	June 7	10.30	2.97	3.4:1
Clover 1 year old	———	Apr. 2	3.08	1.66	1.8:1
Clover 2 years old	———	Apr. 2	9.17	7.19	1.2:1

From these figures, Schubart estimated the total dry weight per acre of the root systems of mature wheat, winter rape, and of one-year and two-year clover to be 748, 2,979, 498, and 2,157 pounds, respectively.

Nobbe (1862) studied the effect of certain nutrient salts upon the development of the root systems of corn plants grown in clay soil contained in glass cylinders. The experiment was so arranged that the nutrient salts were added only to definite regions of the soil contained in each cylinder. Six vessels were prepared, in each of which the salts were distributed in the soil after the following manner. In the first cylinder the salts were equally distributed throughout the whole soil mass. In the second the salts were added only to a layer of soil at the bottom. In a third the salts were mixed with a thin horizontal layer of soil near the center of the cylinder. The fourth cylinder contained the nutrient salts in a layer of soil three or four centimeters beneath the surface. The nutrient salts were distributed in a vertical layer of soil around the edge of a fifth cylinder, while the sixth contained a central core of fertile soil extending from the top to the bottom.

The seedlings were grown in distilled water and in June were transferred to the cylinders. After a growing period of about four months, these plants were harvested and the root systems isolated in the following manner. The entire soil mass was taken from the cylinders, covered with water and left to soak until the roots were entirely free. The root systems were then suspended in water and by gently shaking up and down, the roots took very much the same position that they had occupied in the soil.

The general form of the root systems remained normal and practically the same in all of the experiments. The only difference that appeared was the local variation in the number of root branches. In the unfertilized portion of the soil, the number of branches per unit of length of both the primary and secondary roots remained small, while in the fertilized portions of the soil, the number of branches of both the primary and secondary roots was strikingly large. In the cylinder where the fertilizer was equally mixed throughout the soil mass, the number of branches per unit of length of both primary and secondary roots was the same in all parts of the vessel.

In comparing plants grown in water cultures with those grown in the soil, Nobbe (1869) measured and counted the roots of winter wheat and rye. He found that the roots of the first, second, third, and fourth order of 55-day-old plants grown in the soil numbered 16,000 for rye and 10,700 for wheat, and that the combined length of these roots measured 118 and 82 meters respectively. A mature wheat plant grown in the soil was found to possess 67,200 roots of the first, second, third, and fourth order, with a combined length of 520 meters.

Theil (1865) grew oat plants in a clay soil and then determined the number of roots in a 400-square-centimeter cross section of soil at the depths indicated in Table 3.

TABLE 3.—*Number of roots of oat plants in a 400-sq.-cm. cross-section of clay soil at various depths.*

Depth in centimeters.	Number of roots.	Depth in centimeters.	Number of Roots.	Depth in centimeters.	Number of roots.
25	90	65	39	95	29
35	78	75	33	105	18
45	74	85	29	115	13
55	48				

Nobbe (1872) grew timothy in 2-year water cultures. The plants were started in May and at the end of October the flasks containing them were placed in a room kept just above freezing. One of the plants taken at this time and dried at 100° C. gave the following weights:

Haulms and spikes, 13.142 grams; roots, 4.095 grams; ratio of the weight of aerial parts to the root weight, 3.2:1.

In the early part of the next year, the flasks were transferred to the greenhouse and on September 9 the plants were harvested. The following is the average weight in grams of seven plants dried at 100° C.:

Haulms and grainless spikes, 25.435 grams; grain, 0.897 grams; roots, 4.983 grams; total aerial weight, 26.332 grams; ratio of weight of aerial portions to weight of roots, 5.2:1; aerial weight less grain, 25.435 grams; ratio of the weight of stems, leaves and spikes to the root weight, 5.1:1.

Clark (1874) examined a squash plant growing in the greenhouse at the Massachusetts Agricultural College and estimated the total length of its roots at 15 miles. His estimate, however, included not only the root system proper but also some 70 nodal roots with all their branchlets.

Theil (1876) states that plants grown in a moist or wet soil show a strikingly small root system in comparison to those grown in a relatively dry soil. He observed that roots growing from a layer of fertile soil into a layer of sand and then again into fertile soil showed a profuse branching in the fertile soil layers, while that part of the root system in the layer of sand was very sparsely branched.

Sturtevant (1882), in connection with Dr. Gilbert, estimated that the corn plants for that year at the New York experiment station produced 1,000 roots in the first 4 inches of soil to 1 root produced below that depth.

Hellriegel (1883) studied the roots of various farm crops in regard to their weight, total length, and number per soil volume at different depths in the soil. Table 4 is a summary of his work in regard to the relative weight of the roots and aerial portions of oats and barley.

In estimating the total length of the root systems, Hellriegel used the following method: A representative number of the different root orders was selected. These roots were then measured, dried, and their organic matter determined. The organic matter for the whole root systems was then determined and from these data the total length of the entire root system was estimated. In this manner, he estimated the total length of the root systems of mature barley and oat plants which were grown in fertile soil to be respectively 40 and 50 meters,

TABLE 4.—*Weight of aerial parts and of roots of barley and oat plants at various stages of growth, with the ratio of tops to roots.*

BARLEY.

Number of plants.	Description.	Weight of aerial parts.	Weight of roots.	Ratio of weight of aerial parts to weight of roots.
		Grams.	*Grams.*	
54	10 days old	1.42	1.03	1.3:1
32	20 days old	17.75	7.35	2.4:1
30	Mature	137.67	11.82	11.6:1
72	22 days old	1.67	.98	1.7:1
60	33 days old	5.80	2.21	2.6:1
60	Booting	12.45	2.96	4.2:1
60	End of blooming	16.78	3.30	5.0:1
36	Mature	19.22	2.68	7.1:1

OATS.

Number of plants.	Description.	Weight of aerial parts.	Weight of roots.	Ratio of weight of aerial parts to weight of roots.
30	Booting	48.41	15.60	3.1:1
29	Blooming	67.71	13.85	4.9:1
30	Mature	85.17	12.72	6.6:1

while the roots of the same plants grown in a poor clay soil had a total length of only 25 to 38 meters.

The number of roots in the soil at various depths was determined by the use of an iron cylinder with a basal area of 400 square centimeters. This cylinder was driven in the soil to the desired depth and the earth removed from around it. The column of soil contained in the cylinder was then broken at the base and the number of root stubs projecting from the basal area of 400 square centimeters counted.

TABLE 5.—*Greatest depth and greatest lateral extent of the roots of various plants, as determined by Goff and Beckwith.*

Investigations in 1884.			Investigations in 1885.		
Plant.	Greatest depth.	Greatest lateral extent.	Plant.	Greatest depth.	Greatest lateral extent.
	Inches.	*Inches.*		*Inches.*	*Inches.*
Garden peas	39	18	Orchard grass	21–36	21
Lettuce	25	12	Kentucky bluegrass	18–37	12
Spinach	24	18	Redtop	22–40	9
Asparagus	24	30	Timothy	34	12
Onion	10	10	Cucumber	24	28
Radish	24	21	Mature corn	34	36
Beet	24	30	Scarlet runner bean	30	48
Parsnip	30	14	Dwarf wax bean	24	24
Carrot	16	12	Yellow Scallop squash	—	102
Muskmelon	16	36	Hubbard squash	—	120
Cabbage	20	18			
Celery	15	15			

Goff (1883–1884, 1886–1888) and Beckwith (1885) investigated the general extent and development of the roots of farm crops, with special reference to horticultural plants. These plants were grown on a clay loam soil 6 to 10 inches in depth, underlaid by tenacious gravelly subsoil. A trench was dug on one side of the plant and the roots laid bare with water from a hose. The plants were examined when they had reached their greatest vegetative growth. Their work in regard to the depth and lateral extent of the root systems may be summarized briefly in Table 5.

Under the conditions of this experiment, the root systems of practically all the plants examined had their main development in the upper 3 to 10 inches of the soil. Many of the roots came to within half an inch of the soil surface. These authors also briefly studied the effect of the depth of tillage on root development. It was found that the number of roots that penetrated to the maximum depth was greatest for those plants grown under the deepest tillage, while the maximum development of horizontal roots was produced by those plants grown under shallow tillage.

A brief review and summary of the investigations of root development at the New York experiment station is given by Booth (1907).

Hickman (1887) found that the depth of seeding has practically

TABLE 6.—*Number of pounds (air dry) per acre of roots, stubble and tops as determined by Woods.*

RESULTS IN 1888.

Plant.	Weight of roots in surface soil.	Weight of roots in subsoil.	Weight of stubble.	Weight of tops.
Clover, in bloom	850	48	——	1,657
Clover, ripe	1,388	72	1,272	——
Wheat, heading	533	58	226	2,554
Wheat, seed in milk	691	43	418	5,411
Wheat, ripe	591	—	595	7,092
Oats	245	48	216	5,037
Barley, heading	370	38	187	2,449
Barley, seed in milk	437	34	509	4,907
Barley, ripe	293	43	355	7,154
Timothy, ripe	5,210	5	2,056	5,254

RESULTS IN 1889.

Plant.	Stubble and roots in first 6 inches of soil.	Roots below 6 inches.	Tops (green weight).
Mammoth red clover (mature)	1,693	122	20,419
Cowpeas (mature)	912	295	15,840
Buckwheat	503	20	——
[illegible] beans	651	79	19,190

no effect upon the root development of the corn plant. He found the total length of the primary roots of plants 2, 4, 6, and 8 weeks of age to be respectively 50, 172, 356, and 495 inches. The ratio of the weight of the stem to the weight of roots was found to be 0.6:1 for plants two weeks old and 3.2:1 for plants four weeks old.

Woods (1888–1889) estimated the total root weight per acre of various farm crops. He marked off a block of earth 2 feet square in the field and dug a trench of convenient width and depth around it. By means of a cord drawn tightly around the block, sections of the desired depth were marked. The earth from each section was then removed and the roots contained therein separated both by the hand and by means of 5/16-inch and 3/16-inch screens. From the weight of the roots found in each block the weight of roots per acre was easily calculated.

Table 6 summarizes the results obtained in 1888–1889 from plants grown on a clayey loam soil 8 to 12 inches in depth underlaid by a heavy clay subsoil.

Hays (1888) made a comparative study of the root development of red, mammoth, alsike, and white clovers and alfalfa. These plants were grown under the same conditions in a rich drift soil 6 feet in depth. The plants were examined at 1, 2, and 5 months of age. Table 7 is a summary of his data for the 5-month-old plants:

TABLE 7.—*Height of tops and depth of roots of clover and alfalfa plants five months old.*

Plant.	Height.	Depth of roots.
Red clover	1 ft.	5 ft. 8 in.
Mammoth clover	7 in.	4 ft. 9 in.
Alsike clover	1 ft.	2 ft. 6 in.
White clover	5 in.	2 ft.
Alfalfa	16 in.	6 ft. 6 in.

Whitney (1889) briefly studied the rooting habits of the cotton plant. Plants grown on light sandy soil were examined directly after the first picking of cotton. Eight plants were examined and their tap roots traced below a depth of 3 feet, but the lateral roots were found for the most part in the upper 9 inches of soil. On the average, each plant had a fresh weight of 16 grams of lateral roots above a depth of 9 inches, and 3 grams between the depths of 9 and 30 inches. For plants grown on heavy clay loam, the average fresh weight of the lateral roots above a depth of 9 inches was 12 grams and of the roots between a depth of 9 and 30 inches, 5.6 grams.

Schweitzer (1889) studied the chemical changes in the corn plant at fourteen periods of its growth between 40 days of age and maturity. In the course of this work some attention was given to the relative weight of the roots, stems, and leaves. Table 8 summarizes that portion of his work.

TABLE 8.—*Dry weights in grams of the stems and leaves and of the roots of the corn plant on various dates, with the ratio of the former to the latter taken as 1.*

Dates.	June 21, 5 plants.	June 26, 3 plants.	July 2, 3 plants.	July 9, 3 plants.	July 16, 1 plant.	July 23, 1 plant.	July 30, 1 plant.	Aug. 3, 1 plant.	Sept. 10, 1 plant.
Stem and leaves....	13.61	21.16	54.81	83.0	193.66	222.74	231.86	384.30	515.55
Roots.............	1.72	1.33	4.36	9.67	18.66	13.30	16.19	24.45	21.70
Ratios............	7.9	15.9	12.5	8.5	10.3	16.7	14.3	15.6	23.7

Morrow and Hunt (1888, 1889, 1890) examined the roots of the corn plant at different periods of growth with the view of ascertaining what roots might be injured by cultivation. The plants were grown on black loam soil 2 feet in depth fall plowed 6 inches deep. A trench was dug beside the plants and the roots laid bare by washing. During the season of 1888, nine 26-day-old plants were examined. These plants were 12 inches in height and together had 94 roots. It was found that of the roots examined 6 inches from the plant, one fourth would have been injured by cultivation 3 inches deep and that practically all would have been broken by cultivation to a depth of 4 inches.

In 1889 the corn was planted on April 29. On May 21 four plants with an average height of 6 inches and on June 15 three plants with an average height of 15 inches were examined. These seven plants had 97 primary roots and of this number 48 were examined at a distance of 6 inches from the plant. At that distance it was found that one-fourth of the roots were in the upper 3 inches of soil. Nearly two-thirds were in the first 4 inches, while over one-third extended below a depth of 4 inches.

During the season of 1890, fifteen plants were examined, ranging in height from 2½ inches to 3 feet. These plants possessed 250 primary roots. It was observed that two-thirds, two-fifths, or one-seventh of these roots would have been broken by cultivation 4, 3, or 2 inches in depth, respectively.

Kraus (1888, 1892, 1894, 1895) studied (1) the effect of soil depth on stem and root development, (2) the accommodation of the roots to different distributions of soil nutrients, (3) the effect of the depth of tillage on production, and (4) the manner of rooting of various farm crops.

Pots 7 and 16 centimeters in depth were filled with soil and sown to field beans and oats. At maturity, the length of the stems of these plants stood in the following ratio:

	Deep pots.	Shallow ptos.
Field beans	100	121
Oats	100	122

In another experiment, boxes 15 and 36 centimeters in depth were filled with the same volume of soil and sown to field beans and oats. At blooming time, the ratio of the length of stems in the deep and shallow pots was as 100 to 115 for the beans and 100 to 104 for the oats plants. It was found that the tap roots of the beans were much shorter in the shallow than in the deep soil, but that the number of secondary roots per unit length was greater in the former than in the latter. The root system of the oats remained unchanged in both cases. Kraus concluded that a root system of the oats type can accommodate itself more readily to shallow soil than can one of the bean type.

To determine the accommodation of the roots to different distributions of soil nutrients, the following method was used. One series of boxes 50 centimeters in depth was filled with 30 centimeters of soil and a layer of sand 20 centimeters in thickness placed on top. Another series of boxes was filled to a height of 30 centimeters with sand and then covered with a layer of soil 20 centimeters in depth. These pots were sown to field beans, flax, and barley, which were harvested at maturity. The results of this experiment are shown in Table 9.

TABLE 9.—*Average length of stem and dry weight per plant of field beans, flax, and barley, grown in alternated layers of sand and soil.*

Crop.	Position of soil layers.	Average length of stem.	Average dry weight per plant.	Ratio of dry weights.
		Cm.	*Grams.*	
Field bean.	Sand above	49.9	2.6	100
	Soil above	57.6	4.1	156
Flax	Sand above	52.0	1.3	100
	Soil above	57.0	1.9	145
Barley	Sand above	59.0	12.2	100
	Soil above	64.0	15.5	127

The effects on root development and crop production of deep and shallow tillage, of distance of planting, and of manuring were studied after the following manner: One series of plots was tilled to a depth of 10 centimeters, and another series to a depth of 20 centimeters. On half of these plots, horse beans were planted 5 centimeters apart in rows 12 centimeters apart, while the other half was planted 15 centimeters apart in rows 30 centimeters apart. Table 10 gives the results obtained.

TABLE 10.—*Dry weights in grams of aerial parts of horse beans variously tilled in wide-spaced and close-spaced plantings on poor and on fertile soil, with the ratios of the weights to those of the shallow-tilled plot in each case.*

Tillage.	Wide-spaced plantings.				Close-spaced plantings.	
	Fertile soil.		Poor soil.		Fertile soil.	
	Weight.	Ratio.	Weight.	Ratio.	Weight.	Ratio.
Shallow	26.6	100	13.7	100	—	—
Shallow, manured	—	—	15.1	110	6.3	100
Deep	29.2	109	14.4	105	—	—
Deep, manured	36.6	136	18.5	134	6.5	102

Kraus gives the following conclusions in regard to tillage: (1) Deep tillage gives greater returns with wide planting than with close planting; (2) manuring produced the maximum results with deep tillage; and (3) a close stand lowers the thriftiness of the individual plants and on this account the root systems remain weaker and consequently make less use of the deeper soils.

King (1892, 1893) studied the extent and manner of rooting of farm crops. In his studies a trench 2 feet wide was dug around the plants so that a prism of soil 1 foot wide and of any desired depth and length was isolated. A framework covered with wire netting was then slipped over the prism of earth and the upper loose soil replaced with plaster of Paris in order to hold the plants in place. Small wires were then pushed through the soil and fastened to the wire cage on each side. The roots, after being freed from soil by means of water from a small force pump, were left suspended on the cross wires in approximately the same position that they occupied in the soil.

The vertical distribution of roots was also studied by using an iron cylinder 12 inches in diameter, with a heavy collar. The cylinder was driven into the ground to the desired depth and after removing the soil from around it, the cylinder with its contained soil was taken up. By examining the core of earth made by the cylinder, the depth of root penetration was observed. By this method, it was observed that the roots of mature clover, oats, barley, timothy, and winter wheat grown on a clay loam underlaid by a stiff clay subsoil penetrated to a depth of 4 feet.

King found the ratio of the dry weight of tops to roots for oats to be 2.2 : 1 ; for barley, 3.3 : 1 ; for clover, 4 : 1 ; and for corn, 7 : 1.

Sanborn (1892, 1893) determined the weight of the roots of various crops per acre. By means of a frame provided with a cut-off slide, columns of soil 2 feet square and 1 inch in height were successively removed from the surface of the soil to a depth of 12 inches. The soil of each column was then passed through a series of sieves and the roots picked out by hand, dried, and weighed. From the data thus obtained, the weight of the roots in each inch of soil per acre was calculated. Table 11 gives a summary of Sanborn's work. The crops examined were grown on a sandy loam soil several feet in depth.

TABLE 11.—*Pounds of roots of various crops per acre inch to a depth of 1 foot (water-free weights).*

Depth in inches.	Oats.	Clover 4 years old.	Corn.		Potatoes.	Timothy.	Barley.	Wheat.	Clover.
			Not cultivated.	Cultivated.					
1	30.4	1,058.4	15.0	17.3	4.5	541.7	33.6	41.3	240.7
2	524.3	1,248.5	57.6	45.6	6.7	279.8	81.1	84.5	449.3
3	531.6	1,181.0	86.4	94.8	6.0	116.9	84.5	99.1	433.9
4	415.2	1,142.4	156.0	168.9	5.5	103.9	63.6	135.6	170.8
5	173.3	508.8	55.4	62.6	7.2	89.8	49.2	64.8	149.3
6	128.9	124.8	43.2	38.8	4.8	38.4	30.0	28.3	137.5
7	17.3	88.8	93.6	16.8	22.0	24.0	6.9	11.5	—
8	15.1	66.2	8.4	8.6	12.2	26.9	5.5	5.7	—
9	13.9	62.1	4.6	7.6	15.6	29.9	6.7	6.2	—
10	12.5	50.4	3.6	5.0	8.4	24.0	5.7	6.0	—
11	14.1	50.2	3.7	5.8	14.6	16.5	5.3	6.0	—
12	11.7	48.5	2.4	6.0	12.2	12.0	3.8	3.6	—
Total..	1,888.5	5,630.1	446.2	480.1	120.0	1,303.8	376.1	492.7	—

Häveler (1892) grew corn and bean plants in vessels that contained alternate layers of sand and a fertile soil rich in humus. He found that wherever the roots passed through the fertile soil, a profuse branching of the several root orders occurred, but that where the roots passed through the layers of sand very little if any branching took place.

Frank (1893) grew plants of corn and peas in such a manner that half of the roots of each plant grew in separate vessels. Each vessel contained the same amount of sand and was watered with the same nutrient solution, with the exception that to one vessel a portion of calcium nitrate was added, while the other received no nitrogen compounds. The results were striking in that the roots from the same region of the same plant developed so differently in the two vessels. In the vessel containing the nitrogen-free medium, only a few small branch roots formed, while the vessel containing the nitrogen compound was filled with a thrifty root growth.

Müller-Thurgau (1894) studied the effect of nitrogen compounds on the secondary root formation of vetch, red clover, maize, beans, sunflower, and alfalfa. He found that when the plants were supplied with a nitrogen salt, their secondary roots were both more abundant and more vigorous than those of plants grown in a medium lacking nitrogen.

Fruwirth (1895) made observations on the extent of the root systems, rate of root growth, and the relative weight of the aerial portions to the weight of roots of members of the pulse family. Table 12 is an abstract of his observations for some of the more common agricultural plants.

TABLE 12.—*Data on root and top growth of various legumes at different periods of growth, as determined by Fruwirth.*

PERIOD I. SEEDING TO THIRTEENTH DAY.

Crop.	Height of stem.	Greatest depth of root.	Rate of root growth from—		Greatest side extent of roots.	Weight of aerial parts.	Weight of roots.	Ratio of aerial weight to root weight.
			Seeding to end of period.	Beginning to end of period.				
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Grams*	*Grams*	
Lupinus angustifolius	8	16	1.2	—	5	0.16	0.06	2.6:1
Chick pea	4	16	1.2	—	10	.16	.11	1.4:1
Garden pea	6	16	1.2	—	14	.19	.14	1.3:1
Horse bean	7	16	1.2	—	9	.14	.11	1.2:1
Common bean	4.5	15	1.1	—	8	.14	.14	1.0:1
Soy bean	5	11	.8	—	8	.08	.04	2.0:1

PERIOD II. THIRTEENTH TO TWENTY-SECOND DAY.

Crop.	Height of stem.	Greatest depth of root.	Rate of root growth from— Seeding to end of period.	Rate of root growth from— Beginning to end of period.	Greatest side extent of roots.	Weight of aerial parts.	Weight of roots.	Ratio of aerial weight to root weight.
Lupinus angustifolius	14	42	1.9	2.9	8	0.32	0.10	3.2:1
Chick pea	13	33	1.5	1.9	15	.39	.20	2.0:1
Garden pea	15	33	1.5	1.9	11	.59	.28	2.1:1
Horse bean	12	33	1.5	1.9	12	.31	.14	2.2:1
Common bean	13	32	1.4	1.9	13	.34	.20	1.7:1
Soy bean	12	16	.7	.5	9	.20	.08	2.5:1

PERIOD III. TWENTY-SECOND TO THIRTY-SIXTH DAY.

Crop.	Height of stem.	Greatest depth of root.	Rate of root growth from— Seeding to end of period.	Rate of root growth from— Beginning to end of period.	Greatest side extent of roots.	Weight of aerial parts.	Weight of roots.	Ratio of aerial weight to root weight.
Lupinus angustifolius	28	48	1.3	0.4	12	1.13	0.18	6.2:1
Chick pea	32	41	1.1	.6	40	2.42	.42	5.7:1
Garden pea	55	45	1.2	.8	30	3.80	.61	6.2:1
Horse bean	30	44	1.2	.7	29	.97	.14	7.0:1
Common bean	43	45	1.2	.8	36	1.54	.30	5.1:1
Soy bean	23	23	.6	.5	28	2.57	.15	17.4:1

Headden (1896) made two observations in regard to the depth to which alfalfa roots penetrate. The plants examined were 6 years of age and grew on a stiff clay soil. In one case, the roots extended downward to a depth of 11.75 feet, and in the other, to 12.25 feet.

Georgeson and Payne (1897) made some studies on the vertical and lateral extent of the root systems of various forage crops. These investigators washed the roots bare and in this manner noted their greatest extent and their general position in the soil. The smaller plants were grown in hills 5 feet each way, while the larger ones were in hills 8 feet apart. The roots were examined when the plants had reached their maximum growth. Table 13 gives their observations for some of the more important Kansas forage crops. The plants were for the most part grown on a black loam soil 8 inches in depth, underlaid by a stiff clay.

TABLE 13.—*Height of plant and depth and lateral extent of roots of various crops, as determined by Georgeson and Payne.*

Crop.	Height of plant.	Greatest depth of roots.	Greatest lateral extent of roots.
	Feet.	*Feet.*	*Feet.*
White milo	4.5	3.25	6.0
Yellow milo	5.5	4.00	6.0
Red kafir	5.5	4.00	5.0
White kafir	5.0	4.00	4.0
Corn	9.0	3.67	5.5
Soy bean	2.5	2.83	3.0

The influence of different fertilizers and of the moisture content of the soil upon the relative weight of roots and tops was studied by Tucker and von Seelhorst (1898). These investigators grew oat plants in zinc cans with a soil capacity of about 17 kilos. The cans were filled with dry soil and the following amounts of water added:

Series I. 14.3 percent, or 41.6 percent of the moisture capacity.
Series II. 15.4 percent, or 45.2 percent of the moisture capacity.
Series III. 16.4 percent, or 48.8 percent of the moisture capacity.

These cans were seeded to oats on April 29. The water content of Series II and III was gradually raised, so that by June 8 the moisture content of the two was as shown in Table 14. Phosphorus, nitrogen, and potassium were used as fertilizers. The plants were harvested on August 9 with the exception of the unfertilized and KN pots, which were harvested one week later. Table 14 gives the average results for two cans. In this table, in the column headed "Fertilizer," K = 1 gram potassium carbonate, N = ½ gram sodium nitrate, and P = 1 gram primary calcium phosphate. Where these quantities are doubled, this fact is indicated as K_2, N_2, or P_2. Table 14 gives the average results for two cans.

The results of this experiment showed the following facts: (1) The weight of the aerial parts increased in both grain and straw with the rising water content of the soil; (2) with but one exception, the greatest weight of roots was produced in the soil with the smallest amount of water; and (3) with but two exceptions the lowest root weight was produced by plants grown in the soil with the mean water content.

TABLE 14.—*Weight in grams of straw and grain, of straw alone, and of roots of oats grown in pots variously fertilized and of different moisture contents, with ratios of weights of aerial parts and of straw to root weights.*

Fertilizer.	Weight of grain and straw.	Weight of straw.	Weight of roots.	Ratio aerial weight to root weight.	Ratio of straw weight to root weight.
SMALLEST MOISTURE CONTENT 14.3 PERCENT.					
	Grams.	*Grams.*	*Grams.*		
None	41.5	23.0	7.7	5.4:1	3.0:1
KP	67.5	37.6	10.8	6.2:1	3.4:1
KPN	68.5	37.3	10.1	6.8:1	3.7:1
KP_2N	68.5	37.7	10.9	6.2:1	3.4:1
KN	38.5	21.8	5.7	6.7:1	3.8:1
KN_2P	79.2	44.6	10.7	7.4:1	4.1:1
PN	75.5	44.0	10.7	7.1:1	4.1:1
PN_2K	74.0	41.3	11.5	6.4:1	3.6:1
MEAN MOISTURE CONTENT 18.4 PERCENT.					
None	47.2	24.5	5.3	8.9:1	4.6:1
KP	83.6	48.2	8.3	10.1:1	5.8:1
KPN	93.4	53.3	7.1	13.1:1	7.5:1
KP_2N	94.4	51.0	8.5	11.0:1	6.0:1
KN	40.0	22.1	4.3	9.1:1	5.0:1
KN_2P	108.0	63.1	8.9	12.1:1	7.0:1
PN	101.5	56.7	6.6	15.2:1	8.5:1
PN_2K	99.5	55.1	8.6	11.5:1	6.3:1
HIGHEST MOISTURE CONTENT 22.5 PERCENT.					
None	68.5	36.4	7.2	9.4:1	5.0:1
KP	99.5	55.8	8.4	11.8:1	6.6:1
KPN	119.5	66.7	7.6	15.7:1	8.7:1
KP_2N	135.0	74.7	9.1	14.8:1	8.2:1
KN	63.5	39.1	8.1	7.8:1	4.8:1
KN_2P	127.5	73.7	8.6	14.8:1	8.5:1
PN	126.0	69.7	9.0	14.0:1	7.7:1
PN_2K	117.5	65.3	7.3	16.1:1	8.9:1

Ten Eyck (1899, 1900), using the method devised by King, isolated the root systems of various farm crops growing on the North Dakota station. The plants were grown on a fertile loam soil having a depth of over 4 feet. He found that the roots of mature spring wheat grown on fall-plowed land in drill rows 6 inches apart penetrated the soil to a depth of 4 feet. Mature oat plants grown under the same conditions showed a like depth of root growth. It was observed that the roots of corn at maturity occupied the soil to a depth of 3½ feet and that many of the lateral and secondary roots came to within 1 inch of the soil surface. The roots of mature potato plants in this soil extended 2 to 3 feet in depth, while the tap root of the sugar beet reached a depth of 3½ feet. The lateral roots of these two last-named plants extended horizontally from 2 to 3 feet.

Rimbach (1899), Freidenfelt (1902), and von Alten (1909) have studied and compared the root systems of numerous plants. These authors took up the study with a view to forming a general classification of roots. They claim that root systems can be grouped into rather definite types and that these types will hold fairly well, without regard to the conditions under which the plant is grown.

Preston (1900) examined the roots of several species of cacti growing in the vicinity of Tucson, Ariz. He found that each plant of the species examined had two distinct root systems, a horizontal one which functions mainly in absorption and a vertical one serving as an anchorage for the plant. The depth of the horizontal system depends on the depth of the soil moisture and the nature of the soil, but in the cases examined it was about 4 inches below the soil surface. The horizontal system is much less elastic than the vertical one and the xylem tissue of the former is composed mostly of vessels while that of the latter is composed for the most part of wood cells.

Arker (1901) found that the rate of root growth of plants grown both in soil and water cultures was increased by a stream of air being constantly pulled through the medium in which the plants grew. His work was carried on with *Lupinus albus* and the common sunflower.

Cottrell (1902) examined the root system of an 8-year-old alfalfa plant growing in a stiff hardpan subsoil and traced the tap root to a depth of over 10 feet.

Since, in an earlier experiment (1898) the application of fertilizer to the soil was found to increase the weight of the root systems, von Seelhorst (1902) carried on some experiments to determine if the use of fertilizers did not increase the number and depth of the roots. Spring wheat, rye, peas, flax, beans, potatoes, beets, and two strains of barley were examined at maturity. These plants were grown separately on two series of plots. One series had been fertilized annually for 25 years with fertilizers containing nitrogen, phosphorus, and potassium, though the amount applied is not stated. The other series of plots had received no fertilizer at any time. The number of roots at various depths was determined by the method of Hellriegel

(1883). An iron cylinder 314 square centimeters in cross section was used. The total numbers of roots observed in the cross sections of the cylinder on the eight fertilized and unfertilized plots are shown in Table 15.

TABLE 15.—*Total numbers of roots of various crops found at different depths in 8 fertilized and 8 unfertilized plots.*

Plots.	Number of roots at depth of				
	25 cm.	50 cm.	75 cm.	100 cm.	125 cm.
Fertilized	500	307	197	109	52
Unfertilized	459	206	158	92	43

From these observations, von Seelhorst concluded that fertilizing the soil not only increases the weight of the roots, but also their number and depth of penetration and that on this account, plants grown on a fertilized soil would be in better condition to withstand drought than those grown on unfertilized land.

Von Seelhorst and Freckman (1903) grew several varieties of wheat, oats, and barley in soils having water contents of 40, 55, 70, and 85 percent of the moisture capacity. These plants were grown in pots filled with a clay soil to which a quantity of commercial fertilizer had been added. The results (Table 16) represent the average

TABLE 16.—*Weights in grams of grain, straw, and roots of wheat, oats, and barley grown in pots with different water contents, with the ratios of tops to roots at harvest, as determined by von Seelhorst and Freckman.*

WEIGHTS IN GRAMS.

Crop and portion.	Water content (percentage of moisture capacity).			
	40 percent.	55 percent.	70 percent.	85 percent.
Spring wheat:				
Grain	8.8	19.9	27.0	34.5
Straw	11.7	28.2	44.9	52.1
Roots	4.5	7.3	12.3	13.3
Oats:				
Grain	3.7	22.4	41.2	46.8
Straw	5.4	28.0	44.8	56.6
Roots	2.7	10.2	12.8	16.1
Barley:				
Grain	9.0	33.5	32.4	44.1
Straw	17.5	39.2	43.6	59.2
Roots	5.8	9.0	7.0	11.8

RATIO OF TOPS TO ROOTS.

Spring wheat	4.5	6.6	5.8	5.0
Oats	3.3	4.9	6.7	6.4
Barley	4.5	8.0	10.8	8.7

of 3 varieties of spring wheat, 6 varieties of oats, and 3 varieties of barley.

Ten Eyck (1904) continued his study of the roots of farm crops at the Kansas station. For isolating the roots, the method devised by King (1892) was used. The soil in which the plants grew is described as a heavy clay loam 6 to 12 inches in depth and underlaid by a stiff clay subsoil.

The root systems of corn grown from listed and surface planting showed no marked differences. By listing, the primary roots are placed deeper in the soil than are those of the surface-planted plants, but the secondary roots of the listed plants grew upward and filled the upper surface as completely as did those of the surface-planted ones. At maturity, the depth of root penetration was in each case between 4 and 5 feet.

The roots of Blackhull White kafir were found to be finer and more fibrous than those of corn. The primary roots of the mature plant did not extend beyond a depth of 3½ feet. The main mass of the roots was in the upper 18 inches of the soil.

The roots of mature red winter wheat sown with a diskdrill in 8-inch rows reached a depth of 4 feet, though most of the roots were in the upper 12 inches of soil. Oats and barley plants similarly treated had a vertical root extent of 4½ feet with the main root growth in the upper 18 inches of the soil.

The roots of orchard grass two years old formed a dense mat within the first foot of the soil and very few roots penetrated beyond that depth. Bromegrass was found to send its roots down to a depth of over 4 feet, while the roots of the big bluestem (*Andropogon* sp.) exceeded that depth by almost 2 feet. The roots of the buffalo grass reached a depth of 2½ feet and did not form a mat in the upper foot of soil as did those of the big bluestem. Bluegrass formed a mat of roots in the upper 6 inches of soil. A few roots reached a depth of 4 feet, but most of them were in the upper 2 feet of the soil.

The roots of mature cow peas planted with a drill in rows 40 inches apart penetrated the soil to a depth of 4 feet.

Shepperd (1905) continued the work of Ten Eyck (1899, 1900) at the North Dakota station in isolating and studying the roots of farm crops. He found that the roots of winter rye at maturity reached a depth of 3 feet, while several varieties of spring wheat reached a depth of more than 4 feet. The extent of barley and oat roots was found to be less than those studied by Ten Eyck, the roots of oats reaching about three-fourths of the depth observed by him. Emmer roots extended to a depth of 3 feet. Red clover on a 2-year-old sod had roots extending to a depth of 4 feet while the roots of a 3-year-old alfalfa plant penetrated the soil vertically for over 5 feet.

Snow (1905) found that a saturated soil tended to stop the formation of root hairs in corn and wheat, and that air deprived of oxygen stopped root-hair production and retarded growth.

Livingston (1906) examined the roots of wheat seedlings 17 days old that had been grown in a poor soil to which different amounts of stable manure had been added. It was found that the root systems increased in amount with the increased amounts of fertilizer added. This increase was due mainly to the number and length of the secondary roots and the succeeding branches. The number of primary roots remained the same in all the pots. The zone of root hairs for the roots grown in poor soil was found to extend to within 1 to 3 millimeters of the root tip, while normally its limit is 5 to 10 millimeters from the apex.

Schulze (1906) studied the depth of root penetration and the relative weight of the roots and the aerial parts of numerous agricultural plants. He obtained his results by washing out the roots of plants grown in concrete compartments in the field. These compartments were 60 centimeters square and 2 meters in depth. They were so constructed that three sides were walled with concrete while the fourth side opened into a room common to all the other compartments. The fourth side was doubly closed by means of an iron door and by means of iron plates perforated with holes 1 centimeter in diameter. The space between the iron door and the iron plates was sealed with moist sphagnum. The compartments were filled with moist soil which was thoroughly packed. Each compartment was then sown to the crop to be studied. When the desired stage of growth was reached the iron door was removed and the roots washed free from soil by means of a stream of water. The holes in the iron plates served as an exit for the soil and water as well as a screen for the root particles broken off in the process. The roots were freed from all soil, measured, dried, and weighed. Table 17 gives the depth of root penetration and the relative weights of the roots and aerial portions of the plant.

Rotmistrov (1907, 1909) studied the root system of some 30 agricultural plants in regard to their rate of growth, extent, and their general characteristics. The rate of growth of the roots, together with their vertical and lateral extent, was studied in the field after the following manner. A trench was dug in the field 8 to 9 yards in length, 1 yard wide, and 4 feet in depth. In the longitudinal vertical walls of the trench, horizontal holes or chinks 5 centimeters high, 30 centimeters long, and 20 centimeters deep were made at a vertical distance

TABLE 17.—*Length of roots, weight of aerial parts and of roots, and ratio of tops to roots of various crop plants at several stages of growth, as determined by Schulze.*

Crop and stage of growth.	Number of plants.	Age.	Length of roots.	Weight of aerial parts.	Weight of roots.	Ratio of aerial weight to root weight.
Rye:		*Months.*	*Cms.*	*Grams.*	*Grams.*	
Before heading....	9	7	101.9	3.68	1.79	2.0:1
Blooming.........	7	8	199.4	28.80	6.08	4.7:1
Milk stage........	6	9	178.0	46.17	4.66	9.9:1
Wheat:						
Before heading....	8	7½	133.6	3.99	1.88	2.1:1
Booting..........	5	8½	277.2	32.48	9.01	3.6:1
Milk stage........	10	9½	235.0	46.50	4.90	9.5:1
Ripe.............	13	10¼	186.4	31.44	2.89	10.8:1
Barley, ripe.........	13	3	176.2	27.82	2.05	13.5:1
Oats, ripe...........	10	3	232.3	45.40	4.09	11.1:1
Vetch, in bloom......	4	3	216.0	14.00	2.20	6.3:1
Potato..............	4	4	243.0	36.30	15.10	2.4:1

from one another of 10 centimeters and a horizontal distance of 50 centimeters. These holes were closed with small wooden shutters and the whole vertical wall of the trench covered with asbestos paper and finally with boards covered with straw matting.

The plants to be examined were grown in rows on either side of the pit. In order to study the rate of growth and the depth of penetration of the soil at any stage of growth, the boards from the walls of the pit were removed and by pulling aside the shutters of the chinks, observations of the roots could be made. The hole would then be again closed and the boards and coverings replaced. If the chinks became dry they were moistened by means of a fine spray from a hand syringe.

The rate of growth for the roots of most agricultural plants was found to be greatest during the first 15 to 20 days after the germination of the seed. During that period, the average rate of growth for the roots was found to be from 2 to 3 centimeters for each 24 hours. Table 18 gives the observed depth of penetration and lateral extent of

TABLE 18.—*Depth of penetration and lateral extent of the roots of various agricultural plants, as determined by Rotmistrov.*

Plant.	Depth.	Lateral extent.	Plant.	Depth.	Lateral extent.
	Cms.	*Cms.*		*Cms.*	*Cms.*
Corn...............	113	134	Cucumber.........	105	84
Potato..............	60	100	Cotton............	95	104
Black sorghum......	110	80	Rye...............	118	60
Yellow sorghum.....	106	110	Wheat............	103	92
German millet.......	106	92	Beet..............	146	110

the root systems of the more common agricultural plants at maturity.

To examine the general structure of the root systems of mature plants, Rotmistrov made wooden boxes 2.5 centimeters wide, 70 centimeters long and 150 centimeters deep. These boxes were filled with soil, sown to the desired plants, and sunk into the ground in the field. After the plants were mature, the boxes were taken from the ground, one side removed and replaced by a zinc plate filled with nails 1 inch in length. The soil was then washed from the roots and in this manner the entire root system was left suspended on the nails of the zinc plate. The roots were then transferred to paper to be photographed and studied.

Von Seelhorst and Krzymowski (1909), in determining the influence that various moisture contents of the soil have upon the harvest, report the following results in regard to the relative development of the roots and aerial portions of four varieties of spring wheat, grown in soils having a moisture content of 40, 55, 70, and 85 percent of their water-holding capacity. The results reported (Table 19) represent the average harvests for two years expressed in grams per vessel.

TABLE 19.—*Weight of aerial parts and of roots of four varieties of wheat grown in soils of various moisture contents, with the ratios of tops to roots, as determined by von Seelhorst and Krzymowski.*

Variety of wheat.	Determination.	Water content (percentage of moisture content).			
		40 percent.	55 percent.	70 percent.	85 percent.
Schlanstedter:					
	Aerial parts, grams	45.6	64.8	74.1	92.5
	Roots, grams	15.2	20.1	24.1	27.9
	Ratio	3.0:1	3.2:1	3.0:1	3.3:1
Noe:					
	Aerial parts, grams	42.1	62.2	67.2	86.7
	Roots, grams	9.6	16.2	17.1	21.3
	Ratio	4.3:1	3.8:1	3.9:1	4.0:1
Idener:					
	Aerial parts, grams,	40.0	52.1	62.0	73.0
	Roots, grams.	12.0	14.1	16.4	17.7
	Ratio	3.3:1	3.7:1	3.7:1	4.1:1
Galizischer Kolben:	Aerial parts, grams.	38.5	54.8	66.9	79.0
	Roots, grams.	7.7	11.6	13.1	14.5
	Ratio	5.0:1	4.7:1	5.1:1	5.4:1

The effect of the moisture content, fertilizer, and firmness of the soil upon the root development of the seedlings of barley and wheat was studied by Polle (1910). Some of his results are contradictory to those obtained by other investigators for mature plants. For the most part, the root systems in the unfertilized soil were more branched than those in the fertilized soil and the absolute root weight was greater for the former than for the latter. The root branching was more pronounced in the soil with the higher moisture content, both in the fertilized and unfertilized pots. The plants which grew in firm soil had in general more branched root systems than those grown in a looser soil. Plants grown in the firm soil also produced the greatest absolute root weight.

Kiesselbach (1910), in his transpiration work with the corn plant, concluded that in general root development varies inversely as the soil water content. The relative weight of the aerial portions of the plant and the weight of the roots in different soil moisture contents is here quoted:

TABLE 20.—*Weight of tops and of roots of corn grown in soils of various moisture contents, with the ratios of tops to roots, as determined by Kiesselbach.*

Determination.	Moisture content of soil.				
	98 percent.	80 percent.	60 percent.	40 percent	20 percent.
Weight of tops in grams........	91.1	93.1	100.6	92.9	83.2
Weight of roots in grams.......	10.6	13.7	13.9	15.2	15.8
Ratio.......................	8.5:1	6.7:1	7.2:1	6.1:1	5.2:1

Kiesselbach concludes that plants whcih have their early growth in dry soil may be expected better to withstand a later period of drought because they would have a great absorbing surface exposed to the soil particles.

Egorov (1910) found that the ratio of the roots to the total mass of the plant attains a maximum at the beginning and a minimum at the end of the vegetative period. He also found that readily available fertilizers considerably increase the absolute weight development of the root systems but decrease their proportionate amount.

Cannon (1911) has made an extensive study of the root systems of over 50 annual and perennial plants growing in the vicinity of Tucson, Ariz. He found that the(1) root systems of the annuals rarely penetrated the soil more than 20 centimeters and that the greatest root development took place in the upper 4 or 5 centimeters of soil. The depth of root penetration depended upon the depth to which the rains moistened the soil. The(2) cacti were found to have a specialized root system as observed by Preston (1900). Some of the lateral roots of these plants were found only 2 centimeters from the soil surface. Cannon (1913) later studied the roots of plants growing in the Algerian Sahara, and found the rooting habits of plants growing there to be very similar to those of the plants near Tucson.

Gibson (1912) investigated the extent of the root system of the cucumber (*Cucumis sativus*). This plant was grown in a frame 10 by 6 feet and became a full-sized plant bearing 14 fruits, none of which were removed until the plant was mature. The shoot, including all the branches, measured about 32 feet, and bore 140 leaves. All the roots, including the adventitious ones at the nodes, were carefully washed out and measured. The total extent of all the roots of the plant was found to be 281 feet.

McCool (1913) made a most extensive study of the action of certain nutrient and non-nutrient bases on plant growth. This study included a study of the action of certain bases taken both singly and in combination, as well as of various concentrations, upon the root and aerial development of the plants.

Harris (1914) grew seedlings of wheat, corn, and peas in sand with different percentages of soil moisture. The moisture content varied from 11 to 38 percent of the dry weight of the sand. It was found that in general all of the plants produced a proportionately greater root growth in comparison to the aerial parts in the sand with the lower moisture content.

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THE RELATION OF SULFUR TO SOIL PRODUCTIVITY.[1]

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Considerable interest has been aroused recently by the publication of a number of articles on the rôle of sulfur in soils. The authors have taken the point of view that the quantity of sulfur in many soils is low as compared with that of phosphorus, for instance, while the rate of sulfur removal from soils under cultivation is equal to or even in many cases greater than that of phosphorus. Where experiments have been conducted, some crop increases have been obtained from the addition of sulfur by certain investigators both here and abroad,[2] and there seems to be reason to believe that the relation of sulfur to soil fertility has been given too little attention.

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[1] Contribution from the Department of Soils, University of Missouri. This study was conducted in 1914–15 and the results reported in thesis form as partial fulfillment of the requirements for the degree of Master of Arts. Received for publication December 20, 1915.

[2] Among the more important papers on this subject the following may be noted:

Bernhard, —. Versuche über die Wirtung des Schwefels als Dung im Jahre 1911. Deut. Landw. Presse, 39, no. 23, p. 275. 1912.

Boullanger, E. Action du Soufre en Fleur sur la Vegetation. Compt. Rend. Acad. Sci. (Paris) 154, no. 6, pp. 369–370. 1912.

Hart, E. B., and Tottingham, W. E. Relation of Sulfur Compounds to Plant Nutrition. U. S. Dept. Agr., Jour. Agr. Research, 5: 233–250. 1915.

Reimer, F. C. Sulfur Fertilizers for Alfalfa. Pacific Rural Press, v. 87, no. 26, p. 717. 1914.

Tottingham, W. E. Effect of Level of Sulfur Supply on Plant Growth. Wis. Agr. Expt. Sta. Bul. 228, p. 26. 1912.

The experiments here reported were undertaken to throw some further light on this subject, particularly the relation of sulfur to certain Missouri soils. Since the soil analyses at the Missouri station have thus far not included the determination of sulfur, samples of soil were collected from a number of the more important soil types of the state and the quantity of sulfur determined. The analyses were made by digesting the soil in strong hydrochloric acid (sp. gr. 1.115) and determining the sulfur according to the official method. Table 1 shows the sulfur content of these soils. Since they are widely distributed and represent a large area of the state the analyses are of particular interest.

TABLE 1.—*Percentage of sulfur in representative Missouri soils and pounds of sulfur in 2,000,000 pounds of each soil.*

Locality.	Soil type.	Percentage of sulfur.	Sulfur (pounds) in 2,000,000 pounds of soil.
Maryville	Marshall silt loam	0.053	1,062
McBaine	Knox silt loam	.051	1,027
Centralia	Putnam silt loam	.044	897
Bowling Green	Putnam silt loam	.038	778
Hurdland	Grundy silt loam	.030	603
Sedalia	Oswego silt loam	.025	502
Springfield	Crawford silt loam	.016	329
Lebanon	Lebanon silt loam	.015	314
Carthage	Eldon silt loam	.014	297

Since the Eldon silt loam was found to contain the lowest percentage of sulfur it was selected for use in these experiments. It is a soil containing a good supply of organic matter and is fairly productive. The type represents a considerable area in southwest Missouri.

The major part of the work in this study was carried on in the greenhouse with the Eldon silt loam and with sand cultures. It was desired to note the effect of flowers of sulfur or other sulfur compounds upon the growth and appearance of plants, and also to study the action of these substances in the soil itself.

SAND CULTURES.

The experiment with the sand cultures was conducted for the purpose of studying the effect of flowers of sulfur when used in a nutrient solution containing no combined sulfur. This work was carried on in 1-gallon glazed earthenware jars filled with quartz sand that previously had been washed free from sulfates and chlorides. The treatments of these pots were based on Pfeffer's nutrient solution. Two pots received the normal solution and two the same solution modified by substituting magnesium chloride for magnesium sulfate. Another pair received this modified solution and in addition had 1 gram of flowers of sulfur thoroughly mixed into the sand at the beginning of the experiment. Two other pots were given the modified solution and 4.37 grams of calcium sulfate containing 1 gram of combined sulfur.

Sweet corn was used as the crop in this series. The plants reached a height of about 4.5 feet and produced several mature ears. About a month after planting, the corn receiving the normal nutrient solution had made the best growth, that having flowers of sulfur ranked next, those receiving gypsum were third, and the checks which had no form of sulfur in the nutrient solution were poorest. Those having flowers of sulfur showed a darker green color than any of the others,[3] this large amount of chlorophyll being very noticeable throughout the growing period. The leaves on the plants with the other treatments were striated and showed alternating light and dark green lines. The leaves of the plants receiving no form of sulfur had a lighter, almost translucent, appearance and seemed to be greatly deficient in chlorophyll. The flowers of sulfur seemed to show its beneficial effects more quickly than did the gypsum and it produced taller plants during the first part of the period. Later the plants with the gypsum treatments surpassed those receiving sulfur and were also better than those with normal Pfeffer's solution.

When the plants were harvested samples of the sand were taken and tests made for the presence of soluble sulfate. The checks to which no form of sulfur had been added showed that no sulfate was present. All the other treatments still had some soluble sulfate. This showed that some of the flowers of sulfur had been oxidized to sulfate. It was evident from this and also from the increased growth of plants that flowers of sulphur was able to replace, to a certain extent, soluble sulfate in the nutrient solution.

SOIL CULTURES.

CLOVER SERIES.

Three series of pots having the same fertilizer treatments but with different crops—corn, rape, and clover—were used to study the effects of sulfur upon these widely different families of plants. Since only slight increases were obtained from the use of sulfur with the corn and rape series they need not here be described in detail.

[3] Demolon, M. A. Sur l'action Fertilisante du Soufre. Compt. Rend. Acad. Sci. (Paris), 154, no. 8, pp. 524-526. 1912.

The soil treatments in these series were as follows:

1. No treatment.
2. Flowers of sulfur, 150 pounds to the acre.
3. Lime and gypsum.
4. Lime, nitrogen, phosphorus, potassium.
5. Lime, nitrogen, phosphorus, potassium, and sulfur.
6. Lime, nitrogen, phosphorus, potassium, and gypsum.
7. Lime and sulfur.
8. Lime alone.

The lime was applied at the rate of 2,000 pounds and the gypsum at the rate of 600 pounds to the acre. The other fertilizing elements were supplied by mixing sodium nitrate, mono-calcium phosphate, and potassium chloride into a 3–10–4 fertilizer and applying this at the rate of 600 pounds to the acre. Each treatment was run in duplicate.

The clover had a growing period of 152 days and made a good growth in the pots where plenty of nitrogen, phosphorus, and potassium had been supplied. In the other pots the plants were small and woody and showed very strikingly the lack of fertility in this soil. Circumstances made it necessary to harvest the crop before complete maturity. When the roots were washed from the soil one striking effect of the flowers of sulfur was found. This was the increase in the number of nodules on the clover roots. The effect was most notable where the element was used alone, or in addition to a complete fertilizer. When used with lime, sulfur did not greatly increase the number of nodules. Lime slightly decreased the amount of growth and when used with sulfur a still greater reduction took place.[4] These results may be seen more clearly by a study of Table 2.

TABLE 2.—*Number of nodules produced and air-dry weights of red clover in pots variously fertilized.*

Treatment.	Pot No.	No. of nodules.	Weight of roots and tops.	Pot No.	No. of nodules.	Weight of roots and tops.	Total weight of duplicates.
			Grams.			*Grams.*	*Grams.*
No treatment	17	8	3.65	18	12	3.33	6.98
Sulfur	19	62	5.00	20	80	5.45	10.45
Lime, gypsum	21	5	2.47	22	15	2.86	5.33
Lime, N.P.K.	23	[a]1,000	35.71	24	[a]1,000	33.12	68.83
Lime, N.P.K.S.	25	[a]8,000	33.40	26	[a]7,000	32.05	65.45
Lime, N.P.K. $CaSO_4$	27	[a]800	34.85	28	[a]800	33.20	68.05
Lime, sulfur	29	35	2.85	30	28	2.34	5.19
Lime	31	17	3.08	32	44	2.70	5.78

[a] Estimated.

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[4] A depressing effect of lime during the early growth of plants in pots has been noticed repeatedly in the experimental work at this station. Later in the growing period this depression usually disappears.

It will be noted from Table 2 that where flowers of sulfur was applied alone (Pots 19 and 20), the yield of clover was nearly 50 percent greater than where no treatment was given (Pots 17 and 18), and the number of nodules was about seven times as great. Where heavy applications of fertilizers were given (Pots 23–28) the increase in the number of nodules produced by flowers of sulfur was also about 700 percent, although the total yield of plants was slightly less than where similar treatment was given without sulfur.

The only feasible explanation found for this decerase in the amount of growth in the plants which had the greater number of nodules was that the bacteria had a parasitic action, and on account of the greater infection caused the early growth to be somewhat retarded. For about two weeks before harvest these plants (Pots 25 and 26) showed signs of equalling the growth of the same treatments without sulfur, and possibly might have done so had they not been harvested so early. Where flowers of sulfur was the only treatment given (Pots 19 and 20) the increase in growth over the checks was probably due to the fact that the bacteria was furnishing some nitrogen, in which element the soil was deficient. This element was well supplied in the fertilizers in Pots 23 to 28, and the plants did not need to rely upon the bacteria to furnish their nitrogen.

No-Crop Series.

An experiment was conducted in duplicate in an effort to determine something regarding the action of sulfur in the soil where no crop was growing. Four-gallon pots of soil with four different treatments were used. The soil in these pots was kept up to 23.6 percent moisture. The treatments in this series were as follows:

1. Flowers of sulfur, 150 pounds to the acre.
2. Flowers of sulfur, 300 pounds to the acre.
3. Gypsum, 637 pounds to the acre.
4. No treatment.

At the beginning of the experiment determinations were made for content of nitrate, soluble sulfate, the lime requirement by the Veitch method, and the bacterial count. At the end of 45, 75, and 105 days samples were taken and the analyses repeated. The quantities of nitrate and soluble sulfate were determined colorimetrically. The sampling was done with a 1-inch auger and the borings were made to the full depth of the pots. The auger holes were filled with melted paraffin which was only slightly above the point of solidification. This was to prevent drying out and to avoid any disturbance of the soil for the next sampling. The results of the analyses are shown in

TABLE 3.—*Content of nitrate and sulfate, lime requirement, and total number of bacteria in the soil of the no-crop series at various dates.*

NITRATES (PARTS PER MILLION).

Date.	No treatment (checks).	Sulfur 150 lbs. per acre.	Sulfur 300 lbs. per acre.	Gypsum 637 lbs. per acre.
December, 1914	20.0	20.0	20.0	20.0
January, 1915	48.5	39.0	33.7	38.7
February, 1915	29.7	28.3	23.5	24.1
March, 1915	38.0	42.0	44.0	41.0
SULFATES (PARTS PER MILLION).				
December, 1914	36.4	36.4	36.4	36.4
January, 1915	21.2	32.4	33.8	37.5
February, 1915	54.3	50.8	61.5	60.4
March, 1915	25.3	40.8	53.8	49.8
LIME REQUIREMENT (POUNDS).				
December, 1914	3,389	3,389	3,389	3,389
January, 1915	2,600	2,600	2,850	2,600
February, 1915	4,800	5,526	6,200	5,100
March, 1915	4,852	5,314	4,967	4,390
TOTAL NUMBER OF BACTERIA.				
December, 1914	3,783,000	3,783,000	3,783,000	3,783,000
January, 1915	3,300,000	3,850,000	3,900,000	4,050,000
February, 1915	4,500,000	3,920,000	5,750,000	5,550,000
March, 1915	6,850,000	5,550,000	4,850,000	7,850,000

Table 3. Since the duplicates checked very closely only averages are given.

The results shown in Table 3 indicate that there is a positive correlation existing between the amount of soluble sulfate and the lime requirement. When the active sulfate increased the soil became more acid. When the amount of sulfate was reduced the lime requirement was also less, except in two cases where there was a slight variation.[5] The nitrate content showed a marked negative correlation with the sulfate content and lime requirement. That is, where the soluble sulfate or acidity showed an increase, the amount of nitrate was decreased and vice versa. The bacterial count showed no consistent correlation with any of the other determinations, but did show that it was affected by some of the treatments. Flowers of sulfur seemed to increase the number of bacteria for a time but later caused it to fall below the number in the checks. This was possibly due to the greater acidity in the soil treated with sulfur. The gypsum treatment gradually increased the number of bacteria, the total number being more than doubled during the course of the experiment. The result may have been due to the fact that gypsum seemed to reduce very slightly the acidity, or it may have had some other stimulating effect upon the bacterial flora.

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[5] Lint, H. C. Influence of Sulfur on Soil Acidity. Jour. Indus. Eng. Chem., 6, no. 9, pp. 747–748. 1914.

SUMMARY.

From the results obtained in this study the following brief summary may be given:

Flowers of sulfur partly took the place of a soluble sulfate in a nutrient solution when used in a sand medium, and had a marked effect upon the production of chlorophyll in corn plants.

When used alone flowers of sulfur was slightly beneficial to the growth of corn and rape and still more beneficial to the yield of red clover on the type of soil used in these experiments.

Flowers of sulfur very markedly increased the production of nodules on the roots of red clover.

Flowers of sulfur was oxidized to sulfate in both sand and soil cultures. It slightly increased soil acidity, and the lime requirement was directly correlated with the amount of soluble sulfate.

The nitrate content varied inversely with the amount of soluble sulfate in the soil.

EUGENE WOLDEMAR HILGARD.

It is generally conceded in scientific circles that not the quantity of work accomplished, nor yet the nicety in mechanical execution thereof, but rather the ability to conceive great ideas, to visualize methods of attack on problems, and to interpret results are marks of the eminent scientist. In rare instances, it chances that scientific men of the latter class combine prodigious industry with their other powers and thus compass the accomplishment of a great quantity of work of major significance. Professor Hilgard was one of these rare spirits. Endowed with unusual powers for thinking clearly and reared in a generation by and circumstances in which breadth of education and general culture were prized above the specialist's precision, Dr. Hilgard possessed both the breadth of training and the vision necessary to the task of laying the foundation of a great branch of science.

No brief memorial note such as this can do justice to Hilgard, the man or the scholar. We can only point to large results which he accomplished in grand divisions of his chosen work. He was the first among soil scientists systematically to correlate soils with plant growth through a study of vegetation as it has established itself on virgin land. He was among the first to teach the practical bearings of such correlation when studied in connection with farm experiences. He was among the first to point out the value of a knowledge of geology and mineralogy to a useful appraisal of modes of soil formation and of the chemical and physical properties of soils. He was probably the first to point emphatically to the necessity of correlating different phases of the subject of soil constitution and to show that no one soil character alone could be safely used as a criterion of its adaptability for crops and of its need for fertilization. He was among the first to advocate and introduce proper methods of soil mapping and classification and to point to their value for soil study and soil management. He was the first to elucidate properly some of the very striking relationships between climate, soil formation, and soil constitution. He was among the first to investigate systematically and to explain in modern terms, the origin of alkali in soils and to recommend methods for the reclamation of alkali land. He was among the most important contributors to our early knowledge of soil colloids and soil sediments, and was the inventor of the valuable churn elutriator which bears his name and which has proved of great value in mechanical soil analysis. He was probably the first to throw light on the origin, composition, and variation in hardpans and on methods for handling them. Other and minor problems which claimed his attention were legion, but "whatever he touched he illuminated."

It will be noted that the problems and studies which engaged Professor Hilgard's attention were those belonging to what we might term the frontiers of his science and such indeed they were. Dr. Hilgard was a blazer of trails, a pathfinder in the vast and uncharted realm of soil science. A contemporary of Lawes, Gilbert, Schloesing, Grandeau, Wollny, S. W. Johnson, and many another eminent pioneer in soil work, Hilgard helped to lay firmly and permanently the foundations of investigational work, the superstructure of which is now so rapidly rearing its majestic proportions in the domain of science. It is no detraction that many statements of Hilgard and his contemporaries have been modified, no slight that many more still remain to be changed. The ability to see far and deep was theirs. They, and Hilgard was second to none among them, have made possible everything which follows and therefore have earned for themselves an enviable place for all time in the annals of a science than which there is none more fascinating.

It is impossible for the writer to close these humble words of appreciation of our late departed brother without adverting briefly to his personal as well as to his scientific character. Dr. Hilgard was essentially a man of strong will and of dignified bearing. From the earliest years of his professional career he was a fighter. Never daunted by opposition, no matter how bitter, he gave no quarter in his striving for what he deemed right and proper. The numerous battles which he won attest his skill, determination, and impressive personality. Yet I would not leave my readers with the impression that this well-developed fighting spirit rendered Professor Hilgard austere and forbidding. Quite the contrary. He possessed a smile and a sense of humor which disarmed all and which surpassed in their impressiveness even his fighting mien. Possessed of a remarkable memory, Professor Hilgard would relate many of the humorous experiences of his early years with a charm of manner and an eloquence of diction which were the admiration of all those who were fortunate enough to know him. A cultivated gentleman, courtly in manner, and possessed of a thorough knowledge of several languages and a rich experience of men and things on different continents, Dr. Hilgard was indeed a figure which loomed large in the world.

It was therefore with singular pride that we counted Dr. Hilgard a fellow worker. For the generations which follow him there will always be found exaltation in his courage, noble ideals in his aspirations, and rejoicing in his achievements. Last, but not least, we shall always gather strength from the memory of a firm, yet kindly and genial spirit which, undeterred by delicate health and undismayed by failure or disappointment, sought with constancy and singleness of purpose *truth* for its own sake.

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EFFECT OF RATE AND DATE OF SOWING ON YIELD OF WINTER WHEAT.[1]

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Kansas Agricultural Experiment Station, Manhattan, Kans.

The best rate and the best date to sow winter wheat in the various wheat-growing areas of the United States have been investigated for one or more years by many of the experiment stations. In all the older wheat-growing regions these questions are thought to be fairly well settled. The conclusions arrived at, however, have usually been based upon results secured from different rates sown on only one date in any one year, or from only one rate sown on various dates. As far as the writer is aware, experiments have never been reported in this country that included all the different rates under investigation sown on a number of dates the same season or that included a number of rates sown on all the different dates.

There are many conflicting opinions among the farmers of Kansas regarding the best rate and the best date to sow winter wheat. Until recently, advice given by the station was based upon results secured from rate-of-seeding and date-of-seeding trials conducted in the usual manner, which did not bring out the relation between the rate and the date of seeding on the yield produced. Not always did our advice prove satisfactory. In fact, unless it so happened that the farmer sowed his wheat about the same time of the year as that at which our results were obtained from a certain rate, our recommendations usually did not prove satisfactory. The station usually recommended a specific rate without regard to the time of seeding. Farmers generally are unable to sow their wheat in Kansas at the same time every year. It would be unwise for them to do so, even if it were possible, because of the fluctuations in the weather conditions and consequently in the fitness of their soil on the same date each year.

Wheat is sown in Kansas all the way from the last week in August to the second week in November, but the same rate of seeding is used whether the seed is sown early in September or in November. The station usually recommended from 3 pecks to the acre in western Kansas to 6 pecks to the acre in eastern Kansas, the rate increasing from west to east in proportion as the rainfall increases. About

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[1] Revision of a paper presented at the annual meeting of the American Society of Agronomy at Berkeley, Cal., August 10, 1915.

September 15 was considered the best time to sow wheat in northern Kansas, and October 5 in the southern part of the state.

In trying to analyze the reasons for differences of opinion as to the best time and rate for sowing winter wheat, the thought occurred that the date upon which winter wheat was sown might affect materially the rate of seeding. In order to obtain definite information on the subject, an experiment was started in the fall of 1912 on the agronomy farm near Manhattan, Kans., and a year later at the Fort Hays Branch Experiment Station at Hays, Kans. The results of the three years' trials at Manhattan are now available and are here reported.

Twenty-four fortieth-acre plats, 7 feet by 155.6 feet, were seeded in the fall of 1912. Four plats were sown September 15 at rates of 2, 4, 6, and 8 pecks to the acre, respectively. Similar seedings were made at intervals of one week thereafter until October 20. In 1913 and 1914 the experiment was repeated, but with the additional dates of September 8, October 28, and November 4.

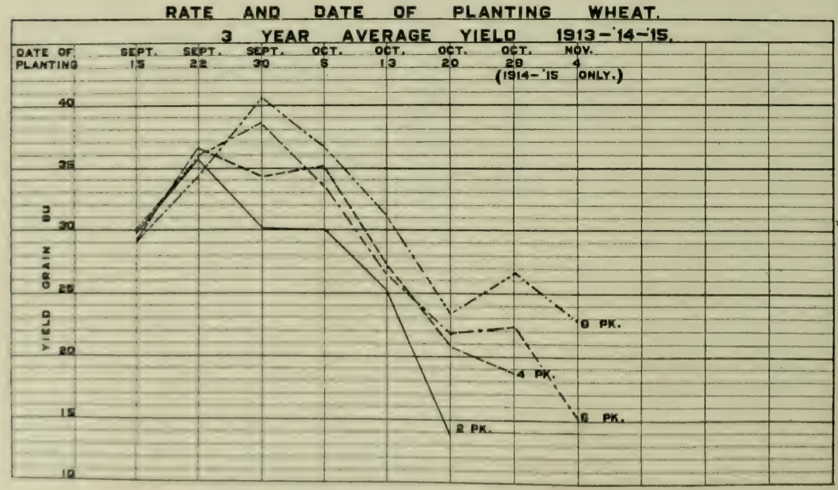

FIG. 6. Graph showing 3-year average yields of winter wheat in bushels per acre obtained in a rate-and-date-of-seeding test at Manhattan, Kans., 1913–15.

The soil used in these trials was as uniform as is ordinarily obtainable in field plot work. As nearly as could be determined, the conditions other than the rates and dates of seeding were alike for all plots.

In Table 1 are presented the yields of grain and straw for all of the rates on the different dates for each of the three years reported, and also the average acre yield of grain produced from each rate. The weight of the straw was not recorded for the crop of 1913. In figure 6 the 3-year average yields of grain are shown graphically.

TABLE 1.—*Yields of grain and straw produced in a rate-of-seeding and date-of-seeding test with winter wheat at Manhattan, Kans., 1913–15.*

Date of seeding.	Rate of seeding.	Yield in 1913.	Yield in 1914.		Yield in 1915.		Average yield of grain.	
		Grain.	Grain.	Straw.	Grain.	Straw.	By rates.	By dates.
	Pecks.	*Bushels.*	*Bushels.*	*Tons.*	*Bushels.*	*Tons.*	*Bushels.*	*Bushels.*
Sept. 15	2	41.47	47.83	3.81	(*a*)			
Do.	4	41.28	46.50	4.00	(*a*)			
Do.	6	41.40	44.50	3.97	(*a*)			
Do.	8	41.76	45.33	3.82	(*a*)			
Sept. 22	2	38.88	45.33	3.81	22.66	2.44	35.62	35.62
Do.	4	40.33	46.00	3.87	23.32	2.59	36.55	
Do.	6	44.07	46.50	3.89	17.32	2.99	35.89	
Do.	8	43.78	46.83	3.95	12.66	2.75	34.42	
Sept. 30	2	37.15	41.33	3.33	15.00	2.71	31.16	36.30
Do.	4	36.00	46.66	2.56	20.66	3.09	34.44	
Do.	6	47.54	46.83	2.32	21.32	2.95	38.56	
Do.	8	51.85	48.16	3.99	22.00	3.21	40.67	
Oct. 6	2	33.98	34.83	2.97	24.32	3.55	31.04	34.94
Do.	4	38.30	43.83	3.60	23.32	2.99	35.15	
Do.	6	40.33	44.50	3.81	26.00	2.53	36.94	
Do.	8	38.30	44.66	3.83	27.00	2.82	36.65	
Oct. 13	2	20.74	26.00	2.16	20.32	2.25	22.35	27.80
Do.	4	23.33	34.00	2.89	25.00	2.55	27.44	
Do.	6	25.05	36.83	3.23	28.66	2.84	30.18	
Do.	8	26.20	41.16	3.62	26.32	2.67	31.22	
Oct. 20	2	14.11	13.50	3.47	17.32	1.61	14.97	20.26
Do.	4	15.84	20.66	3.94	26.00	2.36	20.83	
Do.	6	20.01	22.83	2.29	22.66	2.64	21.83	
Do.	8	19.44	25.50	2.49	25.32	2.80	23.42	
Oct. 28	2	. . .	16.00	3.72	10.32	.95	13.16	20.24
Do.	4	. . .	22.83	2.05	14.66	1.44	18.74	
Do.	6	. . .	29.50	2.76	15.32	1.66	22.41	
Do.	8	. . .	33.33	3.02	20.00	2.00	26.66	
Nov. 4	6	. . .	24.50	2.43	6.00	1.12	15.25	19.04
Do.	8	. . .	30.00	2.79	15.66	1.75	22.83	

[a] Crop destroyed by Hessian fly, as was also that sown one week earlier.

In studying the yields in Table 1, the reader should keep in mind the fact that the greater part of Kansas wheat is sown at the rate of 45 to 60 pounds to the acre, regardless of the time of the year, and that wheat is sown every year from the first week in September to the last of November. It should also be kept in mind that farmers seldom succeed in sowing their wheat on the same date two years in succession, or in an equally good seedbed every year.

According to these results, 2 pecks of seed produced as large yields as 4, 6, or 8 pecks when sown before the last week in September, but after that date heavier seeding produced substantially larger yields almost every year. The difference in favor of the heavier seeding bcomes more apparent as the season progresses until we find that 8 pecks of wheat sown from the second week in October up to November 1 produced almost twice as large yields as 2 pecks.

From field observations, it is clearly evident that Turkey winter wheat stools very heavily when sown early in the season. Consequently, if the plants are not damaged by the Hessian fly, they stool so abundantly as to completely cover the ground when seeded at the rate of 2 pecks. As the season advances and the weather becomes cooler, less and still less stooling takes place. Our field investigations show conclusively that it is unsafe to sow winter wheat anywhere east of the western third of Kansas earlier than September 25 in northern Kansas and October 5 in the southern part of the state, owing to the ravages of the Hessian fly.

The important point brought out by these trials is that there is a distinct relation between the rate of seeding and the time of seeding on the yield of winter wheat produced, a fact that should be kept in mind by the farmer as well as by those giving advice to the farmer.

It will be a very difficult matter for the agronomists of the country to increase the yield of the wheat crop more than 1 or 2 bushels to the acre through breeding alone. If we keep in mind all the factors influencing yield, however, and try to develop more exact information relative to the control of each, the prospect looks bright for adding several bushels to our present yield at very little extra cost to the farmer.

Factors in crop production that seemed not to amount to much ten years ago, or at least were considered secondary to many others, are today looming up large in the face of high land values and worn-out fields. Influences that were considered inconsequential only a few years ago cannot longer be ignored if we continue to produce profitable yields under constantly changing conditions. Many of the agronomic problems that have been considered solved in the past might well be looked into again in order to make sure that all holes are plugged and that there are no leaks to be found. Exact information is needed.

RELATIVE PRECISION OF FORMULÆ FOR CALCULATING NORMAL PLOT YIELDS.[1]

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The literature regarding field experiments with certain of our older agricultural crops is exhaustive, although it is often far from being convincing. The multiplication of experiments has as a rule only increased the number of negative or contradictory results, especially in those cases in which the yield of the crop has been the criterion. The different conclusions which have been reached respecting the effect of applying fertilizers to a crop under supposedly comparable conditions are certainly due in part to the failure systematically to study the possible sources of error, and in part also to the complaisant acceptance of working formulæ at their face value.

In attempting to interpret the somewhat extensive data collected from a series of field experiments with hops extending over a period of six years, advantage was taken of the opportunity to contrast the calculated "normal" and corrected yields on numerous test plots with the actual yields obtained therefrom. These comparisons may prove to be of some general interest or value to workers with crop plants although, in a strict sense, they apply only to a very limited area of a specific crop.

THE NORMAL YIELD OF CHECK PLOTS.

The object of a great many field experiments is to determine the effect of some special treatment upon yield. The practice is quite general to except from special treatment every third, fourth, or fifth row or plot on the experimental area, as checks for use in calculating a standard or normal yield for the treated plots. Numerous formulæ have been proposed for calculating the normal yield from that of the checks, and several of the formulæ in most frequent use have been briefly discussed by Olmstead in his article on Some Applications of the Method of Least Squares to Agricultural Experiments.[2] However, there seems to be a lack of published information on the relative precision of these formulæ and on their absolute precision in specific cases with a definite crop plant, and the desirability of securing evidence on this point is apparent. For this purpose some data obtained in the Sacramento Valley of California from 30 consecutive rows of hops during the six years, 1909 to 1914, were used as a basis for calculating normal yields by five different formulæ. The rows were each 210 feet in length, and the plants in these rows averaged well in number and in uniformity of growth with the plants on several hundred acres of hops in the midst of which the experimental area was located. Since the actual or uncorrected yields of these rows furnish the basis for all the calculations referred to throughout this paper, they are presented in full in Table 1.

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[1] Presented at the twelfth regular meeting of the Washington Section, American Society of Agronomy, Washington, D. C., February 25, 1916.

[2] JOUR. AMER. SOC. AGRON., 6: 190–203. 1914.

TABLE 1.—*Yield, in pounds, of hops from 30 consecutive rows each 210 feet in length.*

Row No.	1909	1910	1911	1912	1913	1914
1	139	123	260	100	137	73
2	128	110	212	158	144	152
3	135	117	235	154	137	119
4	137	118	215	165	144	147
5	155	127	262	187	176	141
Mean..............	139	119	237	153	147	126
6	157	129	247	230	145	167
7	205	169	264	220	146	145
8	188	172	300	220	163	180
9	253	192	330	223	211	167
10	135	140	244	262	130	191
Mean..............	188	160	277	231	159	170
11	189	189	282	133	171	111
12	239	213	315	263	160	161
13	192	197	255	238	171	209
14	179	183	269	231	197	169
15	214	164	251	218	192	204
Mean..............	202	189	274	217	178	171
16	240	195	273	229	239	200
17	179	145	267	270	210	252
18	167	162	199	228	178	216
19	186	195	282	207	253	227
20	164	176	266	269	236	214
Mean..............	187	175	257	240	223	222
21	127	157	214	245	216	231
22	146	166	270	208	257	211
23	157	167	246	274	192	268
24	158	149	283	195	207	163
25	157	144	241	194	206	216
Mean..............	149	157	251	223	215	218
26	161	149	266	199	206	185
27	159	143	282	176	222	214
28	150	156	300	163	197	168
29	130	138	243	173	162	205
30	140	161	264	131	162	153
Mean..............	148	149	271	168	190	185
Mean of all rows.....	169	158	261	205	185	182

The normal yields calculated for the year 1913 from the data in Table 1 are shown in Table 2.

TABLE 2.—*Calculated normal yields of hops in 1913, to show relative precision of various formulæ in calculating normal yields of test rows.*

Row No.	Check or test.	Actual yield in pounds.	Formulæ used.[a] $\frac{c_1+c_2\ldots c_n}{n}=N$		$\frac{2}{3}c_1+\frac{1}{3}c_2=N(A)$ $\frac{1}{3}c_1+\frac{2}{3}c_2=N(B)$		$\frac{1}{2}(c+\frac{2}{3}c_1+\frac{1}{3}c_2)=N$		$\frac{1}{2}(c+c_1)=N(A)$ $\frac{1}{2}(c+c_2)=N(B)$		$\frac{p_1c+p_2[\frac{2}{3}c_1+\frac{1}{3}c_2]}{p_1+p_2}=N$ $p_1=1, p_2=3$.	
			Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.
1	C_1	137	...	...	...	...	...	...	...	...	...	...
2	*A*	144	188	+44	139	− 5	163	+19	162	+18	151	+ 7
3	*B*	137	188	+51	141	+ 4	164	+27	166	+29	152	+15
4	C_2	144	...	...	...	...	...	...	...	...	...	...
5	*D*	176	188	+12	144	−32	166	−10	166	−10	155	−21
6	*E*	145	188	+43	145	0	166	+21	167	+22	155	+10
7	C_3	146	...	...	...	...	...	...	...	...	...	...
8	*F*	163	188	+25	140	−23	164	+ 1	167	+ 4	152	−11
9	*G*	211	188	−23	145	−66	166	−45	159	−52	155	−56
10	C_4	130	...	...	...	...	...	...	...	...	...	...
11	*H*	171	188	+17	153	−18	170	− 1	159	−12	161	−10
12	*I*	160	188	+28	157	− 3	172	+12	179	+19	164	+ 4
13	C_5	171	...	...	...	...	...	...	...	...	...	...
14	*J*	197	188	− 9	193	− 4	190	− 7	179	−18	191	− 6
15	*K*	192	188	− 4	216	+24	202	+10	213	+21	209	+17
16	C_6	239	...	...	...	...	...	...	...	...	...	...
17	*L*	210	188	−22	243	+33	215	+ 5	213	+ 3	229	+19
18	*M*	178	188	+10	248	+70	218	+40	220	+42	233	+55
19	C_7	253	...	...	...	...	...	...	...	...	...	...
20	*N*	236	188	−48	254	+18	221	−15	220	−16	237	+ 1
21	*O*	216	188	−28	255	+39	221	+ 5	222	+ 6	238	+22
22	C_8	257	...	...	...	...	...	...	...	...	...	...
23	*P*	192	188	− 4	240	+48	214	+22	222	+30	225	+33
24	*Q*	207	188	−19	223	+16	205	− 2	197	−10	214	+ 7
25	C_9	206	...	...	...	...	...	...	...	...	...	...
26	*R*	206	188	−18	203	− 3	195	−11	197	− 9	199	− 7
27	*S*	222	188	−34	200	−22	194	−28	192	−30	197	−25
28	C_{10}	197	...	...	...	...	...	...	...	...	...	...
+Deviations..........				230		252		162		194		190
−Deviations..........				219		176		119		157		136
Total...............			(13.3%)	449	(12.7%)	428	(8.3%)	281	(10.4%)	351	(9.6%)	326

[a] In these formulæ, *c* equals average yield of all the checks; c_1, c_2, etc., equal yield of checks C_1, C_2, etc.

The rows which are numbered from 1 to 28 were consecutive, and all received the same treatment. With the actual data on yield in hand for all the rows, every third row, Nos. 1, 4, 7, etc., was arbitrarily assumed to be a check, and the normal yield was calculated for the intervening rows. The normal yields determined according to the several formulæ are given in the columns headed "Yield" in the table. The deviations of the theoretical normal yield of each plot from the actual yield of the same plot are given in the columns headed "Deviation." At the foot of the table are given the totals of the plus and minus deviations respectively, and also the sum of all the deviations without regard to sign. The total deviations are expressed as percentages of the total actual yields of the assumed test plots, *A*, *B*, *D*, *E*, etc., and since the deviations under the several formulæ are in each case calculated on a common basis, these percentages are strictly comparable and should indicate the relative precision of the several formulæ.

For the year under consideration the third formula shows the smallest percentage deviation, and it would seem to follow that the normal yields determined by the use of this formula should differ least from the actual yields. However, a study of the deviations row by row shows that this is true in five instances only, rows *D, F, H, O,* and *Q,* while in seven individual cases, rows *A, B, E, I, J, R*, and *S*, the second formula gives results which differ least from the actual yields. On considering next the results which are second in order of difference from the actual yields, it appears that six such cases, rows *G, K, L, M, N,* and *P,* occur under the third formula and nine rows, *A, B, E, H, I, J, Q, R,* and *S,* respectively, occur under formula No. 5. These discrepancies illustrate clearly the false inferences which may be readily drawn from a consideration of averages alone. Moreover, it requires but little imagination to picture the absurd conclusions that may be and perhaps have been drawn from results obtained by the use of one or the other of these formulæ. To make this concrete, suppose these assumed test rows had received a treatment different from that given the checks, and suppose further that the yield of row *A had been actually increased* by the treatment to the extent of 30 pounds. Using the new value for the yield of row *A*, 174 pounds, and the theoretical normal as determined by the formulæ, the conclusions to be drawn respecting the effects of different treatment are as follows:

From formula 1, the treatment decreased the yield 14 lbs. below normal.
From formula 2, the treatment increased the yield 35 lbs. above normal.
From formula 3. the treatment increased the yield 11 lbs. above normal.
From formula 4. the treatment increased the yield 12 lbs. above normal.
From formula 5, the treatment increased the yield 23 lbs. above normal.

Another inherent weakness of these formulæ becomes apparent when the comparisons illustrated in Table 2 are repeated upon other data. Each change in the data which serves as a basis for the calculations brings about corresponding changes in the ratio between the percentages which indicate their apparent relative precision. Use was made of the actual yield in pounds from the same 28 consecutive rows for each of the 6 years, 1909 to 1914. Calculations similar to those shown in Table 2 were made for each year, and a summary of the results is given in Table 3.

TABLE 3.—*Average deviation from actual yields of normal yields calculated by various formulæ, expressed in percentages of mean actual yield.*

	Formulæ (N = normal yield).	1909	1910	1911	1912	1913	1914
(1)	$\frac{c_1 + c_2 \cdots c_n}{n} = (c) = N.$	14.3 [a](5)	13.7 (5)	9.9 (2)	17.5 (5)	13.3 (5)	17.0 (4)
(2)	$\frac{2}{3}c_1 + \frac{1}{3}c_2 = N$ for plat *A*, $\frac{2}{3}c_2 + \frac{1}{3}c_1 = N$ for plat *B*, etc.	13.4 (4)	9.9 (1)	11.2 (5)	13.5 (4)	12.7 (4)	15.2 (2)
(3)	$\frac{1}{2}(c + \frac{2}{3}c_1 + \frac{1}{3}c_2) = N$, etc.	11.1 (1)	12.5 (4)	10.3 (3)	12.2 (2)	8.3 (1)	15.3 (3)
(4)	$\frac{1}{2}(c + c_1) = N$ for plat *A*, $\frac{1}{2}(c + c_2) = N$ for plat *B*, etc.	11.9 (3)	10.9 (2)	11.0 (4)	13.1 (3)	10.4 (3)	19.4 (5)
(5)	$\frac{p_1 c + p_2(\frac{2}{3}c_1 + \frac{1}{3}c_2)}{p_1 + p_2} = N.$ $p_1 = 1,\ p_2 = 3$	11.8 (2)	11.5 (3)	9.8 (1)	9.9 (1)	9.6 (2)	15.1 (1)

[a] The figures in parenthesis indicate the rank in precision of the formulæ for each year.

It is of interest to note that no formula maintained the same relative rank in each of the six years. Some inferences may perhaps be drawn from the fact that No. 5 ranks first 3 times, and No. 1 ranks fifth 4 times. Since there is evidently no way of determining in advance the formula that should be used in any given case to obtain the most accurate results, it would seem that at least for the crop under discussion a very wide margin must be allowed within which variations in yield cannot properly be regarded as significant. The evidence in hand is perhaps insufficient as to the general application of the criticisms which have been made of these formulæ as applied to field work with hops. However, the data upon which the criticisms are founded are sufficiently extensive to afford a basis justifying the suggestion that workers with other crop plants might do well to verify the precision of their formulae before drawing definite conclusions from the results derived from their use.

The lack of precision resulting when the five formulae mentioned in the preceding paragraphs are employed in the manner previously described may be remedied in part by the use of corrected yields and by replication. In order to furnish an example of the use of these methods to increase precision the data from Table 1 were used in calculating the results discussed below.

Effect on Precision of Correcting for Imperfect Stand.

One of the problems encountered in experimenting with field plots, especially those in which the crop is planted in hills, is how to render comparable the yields from plots which are below normal stand in number of bearing hills or plants. A not uncommon method of correcting is to divide the actual yield of the plot by the number of bearing hills and to multiply the quotient by the number of hills comprising a full stand. The result is the corrected yield. In the case of long rows divided into sections or small plots for distributed grouping, the result obtained when the correction for the row is made plot by plot and the corrected yields combined will be found to differ from that given by the first mentioned method of correction. In order to determine the relative precision of results calculated from corrected and uncorrected yields respectively the actual yields given in Table 1 were first corrected to correspond to a full stand of 30 hills to the row. Since each row had been divided into 6 plots the yield of these plots was next corrected to correspond to a full stand of 5 hills and the sum of these corrected yields taken as the second corrected row yield. The mean, the standard deviation, and the coefficient of variability for the corrected and uncorrected yields were then determined and are shown in Table 4.

Table 4.—*Effect on variability of correcting yields to correspond to full stand.*

Year.	Yield of rows in pounds.								
	Uncorrected yields.			Corrected yields.					
				Row of 30 hills.			Six plots of 5 hills.		
	Mean.	Standard deviation.	Coefficient of variation.	Mean.	Standard deviation.	Coefficient of variation.	Mean.	Standard deviation.	Coefficient of variation.
1909	169	33.632	19.90	189	29.240	15.47	188	29.269	15.56
1910	158	26.466	16.11	177	26.874	15.18	177	25.768	14.55
1911	261	29.274	11.21	280	25.497	9.10	280	26.415	9.43
1912	205	43.988	21.45	247	44.808	18.14	249	42.925	17.23
1913	185	34.934	18.88	198	34.380	17.36	196	35.710	18.21
1914	182	41.875	23.00	231	44.449	19.24	229	47.923	20.92
Average			18.42			15.74			15.96

From Table 4 it will be seen that the variability of the yield for individual years with one exception exceeds 10 percent in both corrected and uncorrected yields. The reasons for this variation and for the high value of all the coefficients are not germane to the question under consideration here and will be reserved for future discussion. Inspection of the coefficients of variability will show that those for the uncorrected yields are consistently higher than those for the corrected yields, although the absolute difference varies from year to year. The coefficients of the two groups of corrected yields differ but slightly in any given year and in only one year, 1914, is the difference as much as 1 percent. In four cases the yields corrected on the basis of the 5-hill plot gave a higher coefficient than those corrected on the row basis. Since the number of variates in this case was the same, it is permissible directly to combine and average for comparison the coefficients of each group. From these averages it appears that by correcting the yield on the plot basis, the variability is reduced on the average by 2.48 percent, and by correcting on the row basis there is an average reduction in variability of 2.68 percent, as compared with the variability of the uncorrected yields.

EFFECT OF REPLICATION ON REDUCTION OF VARIABILITY.

Although it is well understood that replication reduces variability, it is desirable to gain an idea of the number of repetitions necessary materially to reduce error in yield of rows of hops, and also to develop a basis for comparing the relative reduction of error in corrected and uncorrected yields which is brought about by repetition. For this purpose the data for 1909 from Table 1 and the corrected yields for the same year were assembled into series. First the means of the groups of adjacent rows were averaged, and then the average deviation of these means from their averages was determined. This average deviation expressed in percentage of the average yield gives an approximate measure of variation. Next the same deter-

TABLE 5.—*Yields of hops in 1909 (in pounds per row) from 30 rows, arranged in groups to show effect of replication on reduction of variability in yield, and effect on precision of various methods of correcting for imperfect stand.*

Correction.	Groups of 5 adjacent rows.		Groups of 5 rows, taking every sixth row.[a]		Groups of 10 rows, taking every third row.[b]		Groups of 15 rows, taking every second row.[c]	
	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.
No correction.	139	−30	176	+ 7	169	0	172	+3
	188	+19	164	− 5	163	−6	166	−3
	202	+33	178	+ 9	175	+6		
	187	+18	162	− 7				
	149	−20	162	− 7				
	148	−21	172	+ 3				
Average	169	23.5	169	6.3	169	4		3
Percentage of deviation		13.9		3.7		2.3		1.8

TABLE 5.—*Continued.*

Correction.	Groups of 5 adjacent rows.		Groups of 5 rows, taking every sixth row.[a]		Groups of 10 rows, taking every third row.[b]		Groups of 15 rows, taking every second row.[c]	
	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.
Corrected to full stand, 30 hills to the row.	162	−27	191	+ 2	190	+1	190	+1
	204	+15	184	− 5	185	−4	189	0
	219	+30	200	+11	194	+5		
	203	+14	188	− 1				
	177	−12	187	− 2				
	171	−18	188	− 1				
Average	189	19.3	189	3.6	189	3.3	189	0.5
Percentage of deviation		10.2		1.9		1.7		0.2
Each of 6 plots in each row corrected to full stand of 5 hills.	160	−28	189	+ 1	187	−1	190	+2
	203	+15	183	− 5	184	−4	186	−2
	217	+29	197	+ 9	193	+5		
	205	+17	184	− 4				
	167	−21	185	− 3				
	175	−13	190	+ 2				
Average	188	20.5	188	4	188	3.3	188	2
Percentage of deviation		10.9		2.1		1.7		1.0

[a] Groups were rows 1, 7, 13, 19, and 25; 2, 8, 14, 20, and 26, etc.

[b] Groups were rows 1, 4, 7, 10, 13, etc.; rows 2, 5, 8, etc.

[c] Groups were rows 1, 3, 5, 7, 9, etc.; and rows 2, 4, 6, 8, 10, etc.

minations were made for various groupings so chosen that the repetitions were 5, 10, and 15 respectively. The results are shown in Table 5.

Inspection of Table 5 shows the greatest variation in the group of adjacent rows with a progressive decrease in variation as the number of repetitions increases. There is also less variation in each of the two series of corrected yields than in the uncorrected yield, indicating in the case under consideration a gain in precision through the use

TABLE 6.—*Summary of effect of replication on reduction of variability in yield of rows and effect on precision of various methods of correcting for imperfect stand, expressed in percentages of deviation from the mean yield.*

Year.	Groups of 5 adjacent rows.			Groups of 5 rows taking every sixth row.			Groups of 10 rows taking every third row.			Groups of 15 rows taking every second row.		
	No correction.	Row correction.	Plot correction.	No correction.	Row correction.	Plot correction.	No correction.	Row correction.	Plot correction.	No correction.	Row correction.	Plot correction.
1909	13.9	10.2	10.9	3.7	1.9	2.1	2.3	1.7	1.7	1.8	0.2	1.0
1910	10.4	9.6	9.3	2.5	2.4	1.7	1.0	0.9	0.7	0.6	0.5	0
1911	4.9	4.7	5.1	0.3	1.9	2.1	0.2	1.6	1.7	0	1.4	1.2
1912	14.6	13.4	13.1	2.5	2.4	2.2	2.0	2.5	2.6	2.1	2.0	1.4
1913	12.9	12.1	12.2	3.8	3.0	3.4	1.0	1.3	1.3	0.8	0.5	0
1914	14.4	12.7	13.1	3.6	3.2	2.5	2.1	0.8	0.8	1.3	2.5	1.5

of corrected yields. To obtain more data on this point, the yields for each of the years 1910 to 1914 were assembled in series in like manner as that for 1909. A summary of these computations is shown in Table 6.

These results, with the exception of those for the year 1911, correspond closely with those obtained for the consecutive rows as summarized in Table 4. In the last series the results are less consistent than in the other series, due probably to the fact that there were but two groups in this series. The year 1911 forms an exception to the general rule, due in part perhaps to the fact that the crop in this year was unusually large and the percentage of stand higher than in any of the other years. From Table 6 it is also apparent that five replications materially reduces variability and that ten replications will give a degree of precision such that fairly reliable conclusions may be drawn from a comparison of average yields on groups of treated and untreated plots or rows each containing as many as thirty hills. The effect on precision of correcting to full stand is not constant and does not in every case result in increased precision.

SUMMARY.

In field experiments with hops, including fertilizer tests and variations in cultural methods, a number of the common methods for determining the normal yield of treated plots have been found of little value. Normal yields for various plots varied widely according to the method of computation, the values in some cases differing from the actual yield by as much as 40 percent.

The errors introduced by the use of current methods of calculating normal yield may be remedied in part by correcting for imperfect stand and by replication. However, correcting to full stand does not always result in increased precision.

Replication brings about a very marked reduction in variability, although with only five repetitions the error is still relatively large.

SEEDING WINTER GRAINS IN FURROWS TO PREVENT WINTERKILLING.[1]

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Introduction.

About 70 percent of the wheat grown in the United States is sown in the fall. Winter wheat yields better, matures earlier, more often escapes hot winds, insects, diseases, and drought, and permits better distribution of labor; hence it is usually preferred to spring wheat wherever it can be successfully grown. Most of these advantages apply also to winter oats and barley, but because they are less hardy than winter wheat probably less than 10 percent of these grains are sown in the fall.

The principal factor which limits the area that may be successfully cropped to winter grain is winter injury, or winterkilling, which may be defined as the injury resulting directly or indirectly from low temperature during the winter. The importance of winterkilling is indicated by the area unadapted to winter grains and also by the damage that frequently occurs in areas where they are generally grown. Any factor, therefore, which lessens the danger from winterkilling is of considerable importance.

It is fairly well known that seeding in furrows similar to those made with a lister, but smaller, will protect plants from winter injury to a certain extent, and this method is used in northern Alabama and Georgia for seeding winter oats. Winter grains sown with a drill survive better than those sowed broadcast, which is probably due in part to the protection afforded by the small furrows in which the grain is placed. This advantage is recognized by farmers in the hard winter wheat belt, where wheat fields are seldom harrowed after seeding, the land being left slightly ridged by the drill. Because of these facts the relative advantages of seeding in furrows as compared to other methods of seeding seem worthy of serious consideration.

Early Experiments.

Probably the first and most extensive experiments to determine the value of seeding in furrows were undertaken by the Kansas Agri-

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[1] Received for publication April 7, 1916.

cultural Experiment Station in the fall of 1888.[2] During the first few years of the experiment the furrows were made about 6 inches deep and 14 inches apart by means of three small shovels attached to the frame of a Buckeye 1-horse drill. In 1893 and throughout the remainder of the experiment an implement known as the Hollinger lister drill was employed. This resembled a hoedrill except that the shoes were larger, were 11 inches apart, and made deeper furrows.

The experiment, which consisted of comparing the yields of a soft wheat sowed in furrows with the same variety sowed with a hoedrill, was continued for nine years. For various reasons, however, yield records were secured in only five. The plots were replicated five times after the first year, but in one year only four plots were harvested. The rate of seeding, with the possible exception of one season in which there is no record, was 5 pecks per acre for the drilled plots and 4 pecks per acre for the furrowed or listed plots.

The average yields for each year and for the five years are indicated in Table 1.

TABLE 1.—*Annual and average yields of grain and of straw of winter wheat sowed in drills and in furrows at the Kansas station, 1890–93 and 1896.*

Year.	No. of plots.	Sown with drill.		Sown in furrows.	
		Yield of grain, bushels.	Yield of straw, pounds.	Yield of grain, bushels.	Yield of straw, pounds.
[a]1890	1	29.83	3,340	35.34	3,380
[b]1891	5	31.90	4,060	29.36	3,080
[c]1892	5	27.63	2,660	27.03	2,480
[d]1893	4	11.58	1,460	19.62	1,760
[e]1896	5	35.63	4,660	31.89	3,360
Average	..	27.31	3,236	28.65	2,812

[a] Original record, Agronomy Office, Kansas Agricultural College.
[b] Kans. Agr. Expt. Sta. Bul. 20, p. 3. 1891.
[c] Kans. Agr. Expt. Sta. Bul. 33, p. 8. 1892.
[d] Kans. Agr. Expt. Sta. Bul. 40, p. 53. 1893.
[e] Kans. Agr. Expt. Sta. Bul. 59, p. 97. 1896.

The average yield for the furrowed plots was 28.65 bushels of grain and 2,812 pounds of straw. The average yield for the plots sowed with the hoedrill was 27.31 bushels of grain and 3,236 pounds of straw, a gain of 1.34 bushels of grain by furrowing, but a loss of 424 pounds of straw.

In three seasons neither drought nor winter injury appear to have been factors in the result. In two of these seasons the rainfall was excessive, causing considerable damage to the grain in furrows. In two seasons (1890 and 1893) the grain sowed with the hoedrill was considerably injured by drought or winterkilling or both. The appearance of the grain in the spring, especially in 1893, was decidedly in favor of that in furrows. The average difference in yield in these two seasons was 6.77 bushels in favor of the grain in furrows. It was observed also in 1892 that the wheat in furrows appeared decidedly the best in the spring because of less injury during the winter. The higher rate of seeding for the drilled plots, together with the favorable season, however, appears to have been sufficient to overbalance any advantage the grain in furrows may have had.

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[2] Shelton, E. M., Cottrell, H. M., and Shelton, William. *In* Kans. Agr. Expt. Sta. 2d Ann. Rpt. (1889), p. 41. 1890.

Considering the abundant and at times excessive rainfall in three seasons of the five and that later experiments have shown the best rate of seeding at Manhattan to be not less than 6 pecks per acre, the showing for the furrow method of seeding is very favorable and indicates its value for areas or seasons where drought and winterkilling are important.

The Georgia station recommended seeding winter oats in furrows 18 to 24 inches apart as early as 1899 and stated that the method had been generally used by the station for several years previous to that date. During the severe winter of 1898–99, oats sowed in this manner survived sufficiently to make a yield of 40 bushels per acre while those sowed in the ordinary manner were practically all killed and the ground resowed in the spring.[3]

The Alabama station obtained an average of 1.9 bushels more from seeding in furrows than from seeding broadcast in a 6-year test. The gain from seeding with a diskdrill was almost as great, 1.1 bushels in a 4-year test.[4] The experiment station is located in the central part of the state where the winters are relatively mild. A larger difference might be expected farther north, a conclusion that is borne out by the fact that the method is quite generally used by farmers in the northern part of the state.

RECENT EXPERIMENTS.

Following the suggestion of Director Jardine, experiments were begun at Manhattan, Garden City, Hays, and Tribune, Kans., in the fall of 1913 to determine the practicability of seeding in furrows for

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[3] Redding, R. J. Wheat and Oats, Rye and Barley. Ga. Expt. Sta. Bul. 44, p. 11. 1899.

[4] Duggar, J. F., and Cauthen, E. F. Experiments with Oats. Ala. Agr. Expt. Sta. Bul. 173. 1913.

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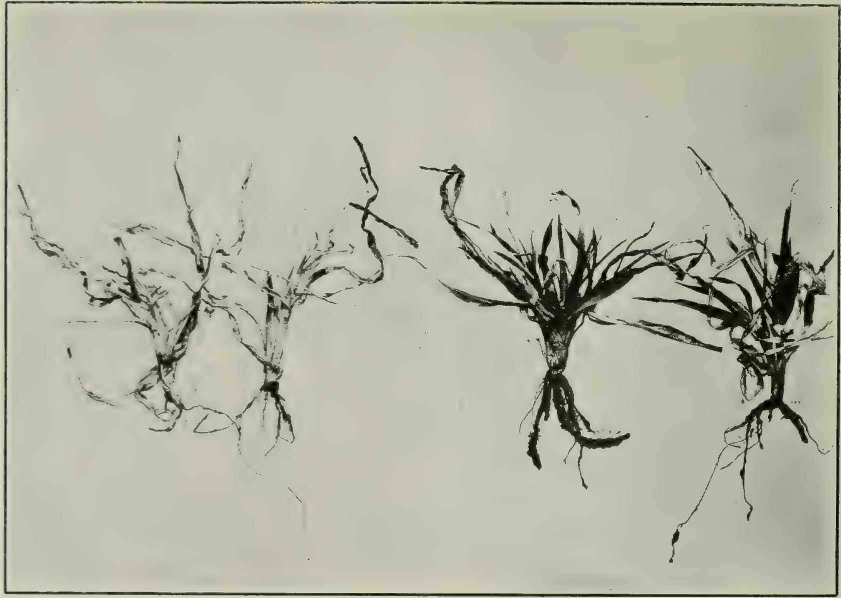

FIG. 1. Typical plants of Tennessee Winter barley from seed sowed in 4-inch furrows (right) and on the surface with an ordinary diskdrill (left). Photographed in March, 1916. Those on the surface were dead, while 87 percent of those in the furrows are alive.

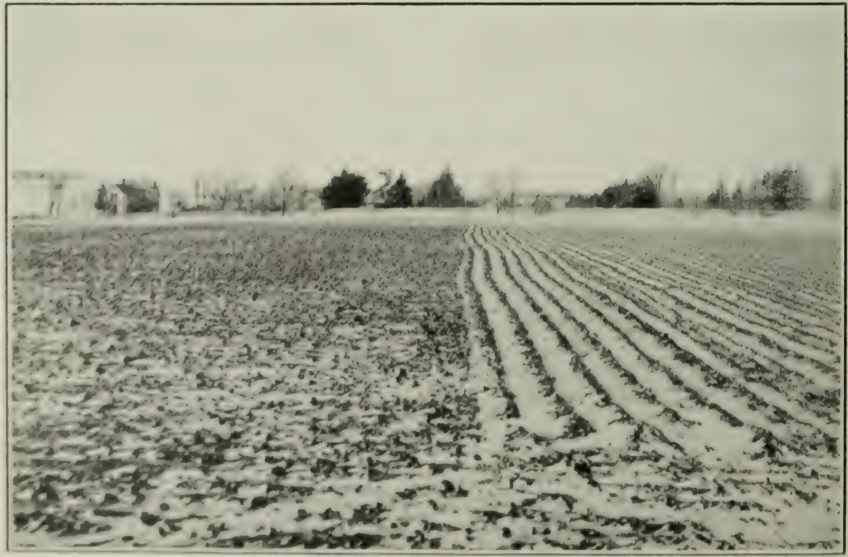

FIG. 2. View of the experimental plots in February, 1916, showing snow lodged in furrows after a high wind.

protection from winter injury and also from blowing of the soil.[5] The experiments were practically a failure at Garden City and Tribune due to lack of a suitable drill and the failure of the grain to germinate with any method of seeding because of exceptionally dry weather. At Hays the grain was sown with a garden drill in furrows previously made. A lister drill with broad shovels similar to those on a corn cultivator was used at Manhattan in the seasons of 1913–14 and 1914–15 and a shoedrill with disk furrow opener attachments in 1915–16.

RESULTS AT MANHATTAN.

The lister drill proved entirely unsatisfactory in that the shovels were placed in two alignments and those in the rear partly or completely filled the furrows made by the forward shovels. This covered the grain so deeply that germination was poor and uneven, and that which did germinate was without the protection which the seeding in furrows was supposed to provide. For this reason the yields of the grain in furrows were not only reduced but were also very erratic and unreliable except for the greatest differences. The percentage of survival was determined for the well-made furrows only and it is believed gives a reliable index of the protection afforded by this method of seeding. Winter wheat, oats, and barley were sown each season. The average percentages of survival and average yields are indicated in Table 2.

TABLE 2.—*Spring survival in 1914, 1915, and 1916, and yield of grain per acre in 1914 and 1915 of wheat, barley, and oats sown in the ordinary manner with the drill (surface seeding) and in furrows at Manhattan, Kans.*

Kind of grain.	1914		1915		1916		Average.	
	Furrows.	Surface.	Furrows.	Surface.	Furrows.	Surface.	Furrows.	Surface.
SURVIVAL, PERCENT.								
Winter wheat	96.0	95.3	100.0	100.0	100.0	100.0	98.7	98.4
Winter barley	96.0	92.5	57.6	30.0	87.0	0	80.2	40.8
Winter oats	86.5	7.5	44.9	33.3	3.0	0	44.8	13.6
YIELD IN BUSHELS PER ACRE.								
Winter wheat	37.8	37.9	17.4	18.7	...	...	27.6	28.3
Winter barley	35.0	38.1	10.3	9.2	...	...	22.7	23.7
Winter oats	26.5	12.3	19.2	18.1	...	...	22.9	15.2

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[5] This method of seeding was suggested, without knowledge of its previous use, by observations during the winter of 1911–12, when wheat in the field protected by the slight ridges made by the drill survived in good condition, while that sowed in the cereal nursery where the ground was smooth was severely injured.

There was practically no killing of wheat in any season, or of barley in 1914. The oats sowed with the ordinary drill killed badly every season. The average survival of two plots sowed with the diskdrill in 1914 was only 7.5 percent as compared with an average of 86.5 percent for six plots sowed in furrows. In 1915 the average survival for the oats was 44.9 percent when sowed in furrows and 33.3 percent when sowed with the diskdrill. The corresponding figures for the barley in 1915 were 57.6 percent and 30 percent respectively. The average survival for the barley in 1916 was 87 percent when sowed in furrows and 0 percent when sowed with the diskdrill (see Plate VI, fig. 1). The corresponding figures for the oats were 3 and 0 percent respectively.

The average difference in survival in favor of seeding in furrows for the three years was 0.6 percent for wheat, 39.4 percent for barley, and 31.2 percent for oats. It should be mentioned that in all three seasons the grain was covered with snow which lay very evenly over the surface during every cold period, except in 1915–16. During this season the grain in furrows at times was protected by perhaps 3 inches of snow while the surface was practically bare.

Even with the uneven and rather poor germination of the grain in part of the furrows because of the unsatisfactoy work of the drill the average yield of oats for the two seasons is decidedly in favor of seeding in furrows, and for the barley and wheat but slightly less than when sowed in the usual manner. There can be little doubt that had a satisfactory drill been available the barley and probably the wheat in furrows would have exceeded in yield that sowed with the ordinary drill.

Results at Hays.

At Hays, Kans., winter oats, emmer, spelt, and barley were sown in furrows from 4 to 5 inches deep and on the surface for comparison.[6] The percentage of survival for three years and the yield in pounds per acre for 1913–1914 are given in Table 3.

The percentage survival at Hays is very decidedly in favor of the grain in furrows except for those cases where the grain was entirely killed or entirely survived. The yield also for the single season reported is decidedly in favor of the grain in furrows, that of oats in furrows being more than three times that of those sowed on the surface. In this season the furrows were 12 inches apart. It was observed that the plants in the furrows were more vigorous and tillered more than those on the surface.

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[6] Kiene, F. A., jr., Ann. Rpt. of Cereal Investigations on the Hays Branch Expt. Sta. in 1914, p. 89, and letter of March 30, 1916.

Table 3.—*Spring survival of winter wheat, barley, oats, emmer, and spelt sown in furrows and with the ordinary drill at Hays, Kans., in 1913, 1914, and 1915, with yields in 1914.*

Kind of grain.	Percentage of survival.								Yield in pounds per acre, 1913–14.	
	1913–14.		1914–15.		1915–16.		Average.			
	Furrows.	Surface.	Furrows.	Surface.	Furrows.	Surface.	Furrows.	Surface.	Furrows.	Surface.
Winter wheat	...	...	100	100	100	100	100.0	100.0	...	...
Winter barley	90	50	45	3	[a]91	[a]60	75.5	37.8	1,955	1,267
Winter oats	50	5	0	0	...	...	25.0	2.5	1,315	370
Winter emmer	90	57	100	50	...	...	93.5	53.5	1,139	704
Winter spelt	95	85	...	...	...	...	95.0	85.0	1,378	727

[a] Average of two plots, one on fallow and one on early fall plowing.

Results in the Nursery at Manhattan.

An experiment less extensive but in some respects more accurate because of the better control that was possible was performed in the cereal crop nursery at Manhattan in 1915 and 1916. In this experiment Turkey winter wheat, Culberson winter oats, and Tennessee winter barley were sown in furrows about 6 inches deep and 20 inches apart, on the top of ridges the same height and distance apart, on the level surface and cultivated, and on the level surface without cultivation.[7] The average percentages of survival are indicated in Table 4.

Table 4.—*Percentage of spring survival of winter wheat, oats, and barley sowed in furrows, on the surface, and on the ridges at Manhattan, Kans.*

Kind of grain.	Furrows.		Ridges.[7]		Surface.			
					Cultivated.		Not cultivated.	
	1915	1916	1915	1916	1915	1916	1915	1916
Winter wheat	96.8	100	100	100	96.6	100	98.6	100
Winter oats	97.4	70	0	0	40.3	0	15.2	0
Winter barley	100.0	100	0	80	40.0	100	35.7	100

It will be seen from Table 4 that the wheat killed very little in any location. The slightly lower survival in the furrows in 1915 was probably due to the fact that, since the grain was sown rather late, the plants were small and some of them were covered with soil before spring.

The oats on the ridges were entirely killed both seasons, and those on the surface in 1916. In 1915, 15 percent of those sowed on the surface survived, 40 percent of those on the surface that were cultivated, and 97 percent of those sowed in the furrows. The corresponding figures for barley were 0, 35, 40, and 100 percent respectively. In 1916 all the oats were killed except those in furrows, of which 70 percent survived. All the barley survived except on the ridges, where 80 percent only were alive in the spring.

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[7] The writer is indebted to Mr. R. K. Bonnett for outlining this experiment and conducting it the first season.

The greater survival in the cultivated as compared with the uncultivated surface in 1915 may be explained by the slight ridges which were thrown up in cultivating the soil and by the greater amount of water that was probably present, it having been observed in another experiment during the same season that winter grain survived best on a wet soil.

The appearance of the grain in the spring on the uncultivated surface and in furrows is shown in Plate VII.

Why Differences in Winter Injury Occur.

Just why grain kills less in furrows than when sowed in the usual manner is not entirely clear and has received very little attention. The Georgia station notes that the injury is much less when the direction of the rows is such as to give the greatest protection from the wind. It has been observed that plants are less likely to be heaved out by alternate thawing and freezing than when sowed in the ordinary way and also that the dirt falling about the plants during the fall and winter protects them to some extent.[8]

The most important effect noted at Manhattan is the protection afforded by snow. With high winds the snow may be entirely blown from a level field, while grain in furrows will be protected with from 1 to 3 inches (see Plate VI, fig. 2). This effect is most pronounced in furrows at right angles to the direction of the wind but is not entirely absent in others. It has frequently been observed that the snow melts soonest on the surface, the grain in furrows often being covered for one to three days after it has entirely disappeared from the surface. This is very important if a thaw is interrupted by a sudden freeze, for the grain in furrows is protected while that on the surface is exposed.

The Relation of Furrows to Temperature.

The relation of seeding in furrows to the temperature to which the grain is exposed was studied experimentally at Manhattan during the

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[8] McClelland, C. K. Winter Crops. Ga. Agr. Expt. Sta. Bul. 117, p. 337. 1915

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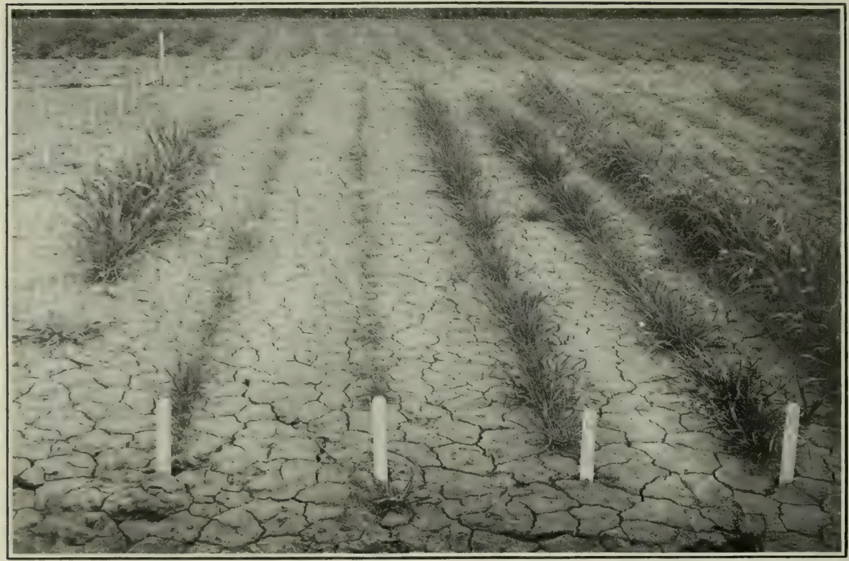

FIG. 1. Winter barley, winter oats, soft winter wheat, and hard winter wheat (left to right) sowed on the surface, not cultivated. Photographed in April, 1915.

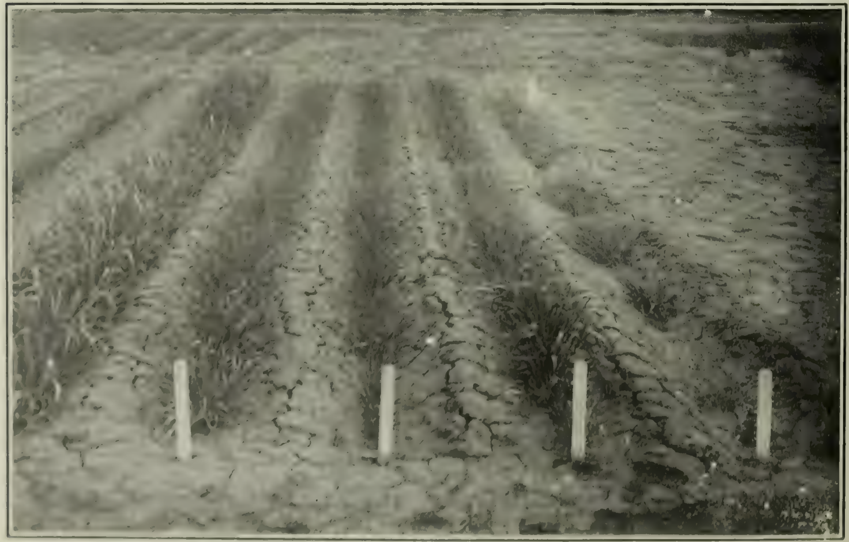

FIG. 2. Winter barley, winter oats, soft winter wheat, and hard winter wheat (left to right) sowed in furrows. Photographed in April, 1915.

winters of 1914–15 and 1915–16. In each case furrows were run in an east and west direction approximately 2, 4, and 6 inches deep. Two thermometers previously compared were placed in each furrow and also two on the surface, with the bulbs in each case covered with about 1 inch of soil. Alcohol thermometers were used the first season, but for the second season electric thermometers manufactured by the Leeds Northrup Company were installed. Three readings daily were made in 1914–15 and four daily in 1915–16. The time of the readings was selected so that approximately the maximum and minimum temperatures each day were recorded. The mean minimum for the entire period, the mean minimum for days with a soil temperature of 0° C. or below, and the lowest recorded temperature in each season are indicated in Table 5.

TABLE 5.—*Mean minimum temperatures, mean minimum temperatures for days when 0°C. or lower was registered, and lowest temperatures (all in degrees C.) recorded on the surface and in 2-inch, 4-inch, and 6-inch furrows at Manhattan, Kans., during the winters of 1914–15 and 1915–16.*

Location of thermometer.	1914–1915.			1915–1916.		
	Mean minimum temperature.		Lowest recorded temperature.	Mean minimum temperature.		Lowest recorded temperature.
	Dec. 3 to March 24.	For days when 0° C. or below was registered.		Dec. 6 to Feb. 29.	For days when 0° C. or below was registered.	
Surface	−0.06	−1.92	−6.8	−2.85	−3.57	−16.06
2-inch furrows	0.20	−1.59	−4.9	−1.86	−2.56	−10.56
4-inch furrows	0.31	−1.22	−4.9	−1.31	−1.95	− 7.44
6-inch furrows	0.59	−0.84	−3.7	−0.93	−1.57	− 6.77

During the first season snow covered the ground to a depth of 4 to 10 inches except for a period of about ten days. There was no drifting, hence the surface thermometers and those in furrows were covered with the same amount of snow except for the difference in the depth of the thermometers below the surface level.

The average minimum temperature for days with a soil temperature of zero or below is seen to be — 1.92° C. for the surface, — 1.59° C. for the 2-inch furrows, — 1.22° C. for the 4-inch furrows, and — 0.84° C. for the 6-inch furrows, an extreme difference of 1.08° C. The lowest recorded temperatures were — 6.8°, — 4.9°, — 4.9°, and — 3.7° respectively, or a difference of 3.1° between the surface and 6-inch furrows and 1.9° between the surface and 4-inch furrows.

These differences it appears were mainly due to the difference in the depth of snow covering the thermometers, since the period when they were not covered was relatively warm, the soil temperature seldom being below zero and never more than —2°. The difference was not due entirely to snow, however, as indicated in figure 6, which shows the daily temperature from January 6 to 9, 1915, when there was no snow on the ground.

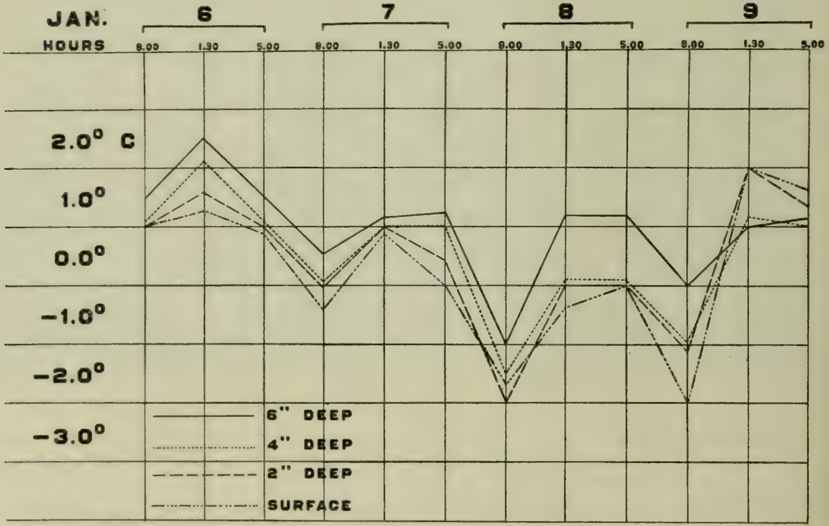

FIG. 6. Graph showing temperatures recorded on the surface and in 2-inch, 4-inch, and 6-inch furrows at 8 a. m., 1.30 p. m., and 5 p. m., from January 6 to 9, 1915.

Considerable wind accompanied with light snows occurred in 1915–1916, hence much of the difference for that season was due to snow lodging in the furrows and partly or entirely blowing off the surface. The average difference in mean minimum temperature for those days with a soil temperature of zero or below was 2° C. between the surface and 6-inch furrows. The difference in the lowest recorded temperature amounted to 9.27° C. as between the surface and 6-inch furrows and 8.26° C. between the surface and 4-inch furrows. The relations that exist are shown to better advantage in figure 7, which presents the daily minimum temperatures during the coldest period of the year.

It will be seen that the minimum temperature for the surface is constantly below that of the furrows except for the brief period from January 20 to 22, when the temperature was near freezing. At the time of the lowest recorded temperature (Jan. 13) the surface thermometers registered —16.1° C. as compared with —9.4° C. for those in the 6-inch furrows or a difference between the surface and 6-inch furrows of 14.4° C. (26° F.), and between the surface and 4-inch furrows of 12.2° C. (22° F.).

Winter wheat and oats were sown in the fall of 1915 in the same furrows in which the thermometer bulbs were placed. This grain was sown late so that growth would be small and therefore have no influence on the soil temperature. The survival of the wheat was 100 percent for the 6-inch furrows, 97 percent for the 4-inch, 95 percent for the 2-inch, and 86 percent for the surface seeding. The corresponding figures for the oats were 68, 39, 2, and 0 percent, respectively.

Depth and Distance Apart of Furrows.

The protection afforded by seeding in furrows depends upon their depth and direction. The yield, however, depends also upon the distance between furrows, which of course must be greater as the furrows are deeper. Since increasing the distance between rows beyond a certain point decreases the yield, this is of some importance.

In the early experiments at Manhattan, at Hays in 1915, and at the Georgia and Alabama stations, the protection afforded by furrows was more than enough to balance any reduction in yield that may have occurred due to wider spacing of the rows. Experiments conducted for other purposes in various parts of the United States do not show any marked effect on yield from spacing the drill rows moderate distances apart.[9]

In general practice drill rows are spaced about 6 inches apart on rich soils in humid areas. In subhumid and semiarid areas rows 7 or 8 inches apart are more generally used. It is probable that in dry areas and on poor soils very little if any loss will be sustained from seeding in drills 12 to 16 inches apart, disregarding the protection that is likely to follow from seeding in furrows. In fact it has been shown that double spacing corn rows may increase the yield in semiarid areas.[10] The advantage here is ascribed to the competition between plants in the row. This retards the vegetative growth, causes the roots to extend downward, and probably reserves a supply of water between the rows for use later in the season, all of which are considered advantages in a dry year. It is not unreasonable to expect a similar advantage for small grains as long as the distance between rows does not exceed the ability of the plants to draw water from the soil. It is of interest to note in this connection that Rotmistrov has demonstrated a lateral root growth for wheat of 92 cm. (36.8 in.), for oats 54 cm. (21.6 in.), and 94 cm. (37.6 in.), according to variety, for two-rowed barley 90 cm. (36 in.), for six-rowed barley 86 cm. (34.4 in.), and for rye 60 cm. (24 in.).[11]

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[9] Foster, Luther, and Fairfield, W. H. Experiments in Wheat Culture. Wyo. Expt. Sta. Bul. No. 48. 1901.

Georgeson, C. C., Burtis, F. C., and Otis, D. H. Experiments with Oats, 1897. Kans. Agr. Expt. Sta. Bul. 74, p. 201. 1897.

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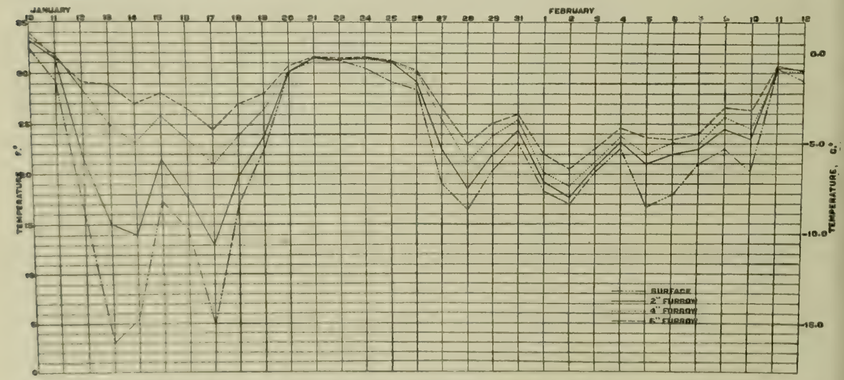

FIG. 7. Daily minimum temperatures on the surface and in 2-inch, 4-inch, and 6-inch furrows, January 10 to February 12, 1916.

SEEDING IN FURROWS IN DRY AREAS.

Probable advantages of seeding in furrows in dry areas or dry seasons are better germination and the protection from blowing. It is well known, for example, that ridging the soil prevents blowing to a large extent. Furthermore, as the plants are below the general surface level they would not be exposed to the moving soil particles and if well started in the fall would probably not be covered sufficiently to cause serious damage.

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[10] Cunningham, C. C. A New Method of Growing Corn. JOUR. AMER. SOC. AGRON., 6: 84. 1914.

[11] Rotmistrov, V. Zhur. Opuitn. Agron. (Russ. Jour. Expt. Landw.), 8 (1907), no. 6, pp. 667–705; 9 (1908), no. 1, pp. 1–24. *Abs. in* Expt. Sta. Rec., 20: 732. 1909.

In dry areas the surface soil is often too dry for germination even when moisture is plentiful a few inches below the surface. This is especially likely to be true where the land is fallowed and summer tilled. In such cases seeding in furrows would aid materially in placing the grain in contact with moist soil and so insure germination.

Possible Disadvantages.

The possible disadvantages of seeding in furrows should be considered. On level, poorly drained land such grain might be injured by water standing in the furrows. On rolling land seeding in furrows would probably increase erosion except where it is practical to seed on the contours of the field. Weeds would possibly have a better opportunity to grow with drills far apart. On the other hand there would appear to be a better opportunity to destroy weeds with a harrow without injuring the grain should they prove troublesome.

At the present time there is no drill on the market for seeding in furrows that may be expected to find favor with farmers in the winter wheat belt. As previously mentioned two drills have been used at Manhattan, neither of which for various reasons has proved entirely satisfactory. It is confidently expected, however, that certain changes being tried at the present time will overcome the difficulties thus far encountered.

Summary.

Since winter grains are generally preferred to spring grains, winterkilling or winter injury is important (1) in limiting the area adapted to winter grains and (2) because of the large losses that frequently occur in areas where they are commonly grown.

Grain sowed with a drill survives better than when sowed broadcast, which is probably due to the slight furrows in which the grain is placed.

Seeding in furrows tends to prevent winterkilling and damage from blowing in dry areas, aids in placing the grain in contact with moist soil, and probably enables the plants to endure drought better than when sowed in the ordinary way. The furrows catch and retain snow, modify the temperature to which the grain is exposed during the winter, protect the plants from the wind, and probably reduce the injury from heaving.

Winter oats sowed in furrows in field plots survived 87.5 percent in one season as compared with only 7.5 percent when sowed in the ordinary way, and winter barley sowed in field plots survived 87 percent while that sowed with a diskdrill was entirely killed.

The yields of wheat do not show a marked advantage from seeding in furrows as compared with the usual method (1) because wheat seldom winterkills or is seriously injured by drought where the two methods have been compared for yield; (2) because of the unsatisfactory work of the drill used for seeding in furrows in part of the experiments; (3) because of differences in the rate of seeding which probably favored the grain sowed in the usual manner; and (4) because of poor drainage in some cases. The yields of the less hardy cereals, oats, barley, spelt, and emmer, are decidedly in favor of seeding in furrows wherever there has been material loss from winterkilling. There is no reason to expect different results from wheat where that cereal is subject to injury.

Grain probably should not be sowed in furrows on poorly drained land, since it is likely to be injured by an excess of water, nor on steep hillsides subject to erosion except where it is practical to run the furrows on the contours of the field.

This method would appear to be especially promising for areas where the supply of moisture is deficient and where the winters are cold and characterized by light snowfall and frequent winds.

THE RELATION OF EAR CHARACTERS OF CORN TO YIELD.[1]

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INTRODUCTION.

Throughout the corn-belt states farmers have been taught in the selection of seed corn to select ears that approach as nearly as possible a standard size, rather rough in type, with covered tips, well-rounded butts, and deep, uniform kernels properly proportioned as regards their other dimensions. While most of these characters are undoubtedly more or less desirable in good seed corn, the relative importance of the various characters as related to yield per acre has not yet been definitely established.

At the Ohio station, Williams[2] studied the relation of a number of the more prominent ear characters to yield. Long ears were compared with short ears, cylindrical ears with tapering ones, ears having well filled tips with ears from which the tip of the cob protruded at least three-fourths of an inch, rough with smooth dented ears, and ears having a high percentage of grain to cob with ears having a comparatively low percentage. Ears with 14, 16, and 18 rows of kernels also were compared. The selections were continuous. The results obtained were largely of a negative character.

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[1] Received for publication February 15, 1916.

[2] Williams, C. G. Corn Experiments. Ohio Agr. Expt. Sta. Bul. 282. 1915.

Ears averaging 9.21 inches in length outyielded ears averaging 6.77 inches in length 1.39 bushels per acre in 40 tests. Cylindrical ears were outyielded by tapering ears 1.65 bushels per acre in 22 tests. In eight tests extending over eight years, ears with well-filled tips produced 0.84 bushel more than ears from which the tip of the cob protruded at least three-fourths of an inch. Smooth dented ears outyielded ears of the rough type 1.76 bushels per acre on the average in a 7-year test. Ears with 88.16 and 76.38 percent of grain to cob, respectively, produced yields varying only 0.42 bushel per acre. Results obtained in comparing ears with 14, 16, and 18 rows were in favor of the ears with the smaller number of rows.

At the Nebraska station, E. G. Montgomery[3] compared smooth and rough ears, the latter the standard type, of Reid Yellow Dent corn selected continuously for a period of four years. The smooth dented type outyielded the standard type 4.56 bushels per acre.

Eugene Funk,[4] an Illinois farmer and corn breeder, reports that in his breeding operations the smooth type of Leaming corn gave considerably increased yields over the standard strain of that variety.

H. H. Love[5] of the Cornell station studied the relation of certain ear characters to yield for a number of ears of Minnesota No. 13 and Funk Ninety Day corn planted in ear-to-row tests. His results indicate that long ears have a slight advantage; that the correlation of cylindrical or tapering ears to yield is so slight as to be insignificant in selecting seed ears; that a small gain in yield may be expected by planting heavy seed ears; and that the number of rows of kernels per ear has no marked effect on the yield.

H. J. Sconce,[6] of Sidell, Ill., compared ears of Reid Yellow Dent and Johnson County White having respectively 16, 18, 20, and 22 rows of kernels. In the nine tests conducted, ears containing 20 rows produced the largest yields five times and ears containing 18 rows gave maximum yields four times.

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[3] Montgomery, E. G. Experiments with Corn. Nebr. Agr. Expt. Sta. Bul. no. 112. 1909.

[4] Funk, Eugene. Ten Years of Corn Breeding. *In* Amer. Breeders' Mag., v. 3, no. 4, p. 295.

[5] Love, H. H. The Relation of Certain Ear Characters to Yield in Corn. *In* Ann. Rpt. Amer. Breeders' Assoc., 1911–12, vols. 7–8, p. 29. 1912.

[6] Sconce, H. J. Scientific Corn Breeding. *In* Ann. Rpt. Amer. Breeders' Assoc., 1911–12, vols. 7–8, p. 37. 1912.

EXPERIMENTS AT THE KANSAS STATION.

The data presented herein were compiled from ear-to-row tests conducted by the Agronomy Department of the Kansas station during the years 1905 to 1909, inclusive, and from two tests conducted in 1912. A hailstorm partially destroyed the corn in 1910 and the crop was a failure in 1911 and 1913 because of drought.

The primary object in conducting these ear-to-row tests was to produce improved strains of corn. At the time the work was started very little attention was given to recording the various ear and kernel characters, but as the work progressed these characters were recorded more systematically. All of the ear-to-row tests were conducted on the station farm on upland loam soil with the exception of the one test with Pride of Saline corn. The corn in this test was grown on creek bottom soil on the Hays Branch Experiment Station, Hays, Kans., in the west central part of the state. The varieties used in the ear-to-row test, the number of ears included in each, and the average yield of the rows in each test are indicated in Table 1.

TABLE 1.—*Number of ear-to-row tests and average yield per row of varieties of corn at the Kansas station, 1905 to 1912.*

Variety of corn.	Number of ears in test.							Average yield in bushels of ear corn per acre.						
	1905	1906	1907	1908	1909	1910	1912	1905	1906	1907	1908	1909	1910	1912
Boone County White	..	19	53	54	79	50	..	..	56.06	56.11	60.29	35.72	21.89	..
Do.[a]	..	40	..	..	..	..	..	..	51.65	..	..	..	..	..
Reid Yellow Dent	..	62	51	46	27	..	..	..	62.62	57.52	76.57	37.02	..	..
Do.[b]	..	..	..	32	..	..	..	..	..	..	58.46	..	..	..
Kansas Sunflower	..	13	46	54	54	..	50	..	48.95	59.63	45.01	37.78	..	27.27
Hildreth Yellow Dent	..	22	52	54	80	..	..	..	75.09	52.41	79.11	53.47	..	..
Do.[a]	..	52	..	..	..	..	..	..	68.24	..	..	..	..	..
Hogue Yellow Dent	..	..	36	26	30	..	..	..	..	45.01	31.69	26.32	..	..
Legal Tender	..	..	39	42	20	..	..	..	..	57.35	46.28	48.14	..	..
Leaming	..	..	..	26	30	..	..	..	..	..	43.47	38.56	..	..
McAuley White Dent	22	..	54	38	..	..	..	68.84	..	56.06	54.52	..	..	..
Pride of Saline	..	..	..	..	..	48	..	..	..	..	..	..	43.34	..

[a] Two ear-to-row tests with this variety were conducted in 1906.

[b] Two ear-to-row tests with this variety were conducted in 1908.

It will be noted that the number of ears included in the various tables which follow vary considerably. This is because it was not always possible to include all the tests for every character classification. In classifying the ears according to length (Table 2), it was necessary to omit four tests due to the fact that short ears were not included. The number of ears in all cases, however, is believed to be sufficient to eliminate all but very small errors.

LENGTH OF EAR AS RELATED TO YIELD.

The ears of corn grown in the ear-to-row tests included in Table 1 were divided into three groups according to their length. Group I included the long ears, Group II the medium ears, and Group III the short ears. In classifying the ears it was not possible to group them according to a definite length each year. Because of seasonal conditions the mean length for the seed ears of a given variety varied according to whether the year was favorable for corn or otherwise. In the favorable seasons the mean length was considerably greater than that for the adverse seasons. In order to obtain comparative results the range of variability with respect to length of the ears for the various seasons was determined and three divisions—long, medium, and short—were established, the ears being grouped accordingly. Table 2 gives the yield data for the three groups for each variety.

TABLE 2.—*Average length of ear and average yield of long, medium, and short ears of nine varieties of corn.*

Variety.	Long ears.			Medium ears.			Short ears.		
	No. of ears.	Average length.	Average yield.	No. of ears.	Average length.	Average yield.	No. of ears.	Average length.	Average yield.
		Inches.	*Bushels.*		*Inches.*	*Bushels.*		*Inches.*	*Bushels.*
Boone County White. .	115	9.20	43.55	102	8.63	47.87	78	8.08	49.96
Reid Yellow Dent.	82	9.41	59.63	77	8.82	58.90	59	7.96	57.41
Hildreth Yellow Dent. .	110	9.55	67.75	101	9.02	64.29	49	8.39	65.69
Kansas Sunflower	118	9.33	42.60	77	8.67	42.63	79	7.97	42.41
Hogue Yellow Dent. . . .	23	9.05	35.63	38	8.54	35.07	31	8.10	33.08
McAuley White Dent. .	39	9.27	54.29	38	8.75	56.79	15	8.28	53.87
Legal Tender	32	9.87	49.51	37	9.22	50.22	32	8.66	51.59
Leaming	24	9.52	40.24	19	8.57	42.57	14	8.03	41.60
Pride of Saline	23	8.70	40.40	19	8.00	39.74	6	7.50	38.05
Average	566	9.32	48.18	508	8.69	48.45	363	8.11	48.18

While the average yield of all varieties indicates that length of ear has no relation to yield, a study of Table 2 reveals the fact that varieties differ as regards this factor. For the larger varieties such as the Boone County White, which requires practically all of the growing period in which to mature, the long ears do not yield as well as those of the other groups, while for the Hogue, Reid, and Pride of

Saline varieties, which mature comparatively early, the long ears yield best. The differences for the two classes counterbalance each other in the averages for all varieties.

CIRCUMFERENCE OF EAR AS RELATED TO YIELD.

The ears included in the ear-to-row tests were divided into three groups according to circumference, similar to the way in which they were grouped as regards the character of length. The indications are that the slender ears are more productive than those with comparatively large circumference. With the exception of the Pride of Saline, a rather early maturing variety, the group of ears with the largest circumference made the lowest average yields. The differences in the yields of the various groups (Table 3) are sufficient to be significant.

TABLE 3.—*Average circumference and average yield of large, medium, and small ears of nine varieties of corn.*

Variety.	Large ears.			Medium ears.			Small ears.		
	Number of ears.	Average circumference.	Average yield.	Number of ears.	Average circumference.	Average yield.	Number of ears.	Average circumference.	Average yield.
		Inches.	*Bushels.*		*Inches.*	*Bushels.*		*Inches.*	*Bushels.*
Boone County White	61	7.45	44.49	131	7.05	45.62	83	6.65	45.11
Reid Yellow Dent	31	7.44	56.41	79	7.12	57.65	47	6.78	57.39
Hildreth Yellow Dent	87	7.75	64.35	108	7.38	67.33	65	6.98	65.32
Kansas Sunflower	57	6.94	41.45	92	6.62	42.84	55	6.13	42.91
Hogue Yellow Dent	23	7.13	34.88	30	6.75	36.45	13	6.37	37.14
McAuley White Dent	29	7.42	57.61	39	7.17	60.45	46	6.75	60.77
Legal Tender	24	7.37	51.24	40	7.00	52.87	17	6.50	51.68
Leaming	4	7.75	38.43	11	7.50	42.75	11	7.25	46.03
Pride of Saline	19	7.00	42.51	22	6.50	38.03	7	6.00	39.90
Average	335	7.36	47.93	552	7.01	49.33	344	6.60	49.58

FILLING OUT OF TIPS AS RELATED TO YIELD.

The covering of the tip is an ear character that receives considerable attention from practically all corn judges and many seed corn growers. The results obtained at the Kansas station as well as those secured by Williams and by Love indicate that the degree of filling out of the tip of the ear has no bearing on productiveness.

The ears included in the ear-to-row tests at the Kansas station were divided into three groups according to whether they had filled tips, tips that were medium well filled, or tips that were poorly filled. The tips of the ears in the first group were not necessarily completely covered, but in order to be included in this group the ears held their size well toward the tip end and were at least partially covered with kernels that satisfactorily maintained their size and uniformity.

Practically all of the ears classified as having poor tips had tips from which the cob protruded more or less or were otherwise deficient. The ears with medium filled tips constitute an intermediate group. The average yields from each class for all varieties are given in Table 4.

TABLE 4.—*Yields from seed ears with well filled, medium filled, and poorly filled tips.*

Character of tips.	No. of ears.	Average yield per acre in bushels.
Well filled	308	51.65
Medium filled	478	51.76
Poorly filled	216	51.77

ROUNDING OUT OF BUTTS AS RELATED TO YIELD.

The ears in the ear-to-row tests were grouped according to the degree with which the corn rounded out over the butts. The classification of the ears into groups was very similar to that for the filling out of the tips. The results given in Table 5 indicate that this character has very little to do with the yield.

TABLE 5.—*Yields from seed ears with well rounded, partially rounded, and not rounded or otherwise poor butts.*

Character of butts.	No. of ears.	Average yield per acre in bushels.
Well rounded	346	50.66
Partially rounded	423	50.96
Not rounded or otherwise poor	168	51.04

INDENTATION AS RELATED TO YIELD.

Most corn growers maintain that rough dented ears are more desirable than those that are comparatively smooth. The smooth type even though the kernels are considerably dented is avoided by most farmers when selecting seed. Every one who has experience in picking seed corn is familiar with the usual correlation of rough type and deep kernels. That roughly indented corn with the correlated deep kernels is associated with high yielding capacity is evidently quite generally taken for granted. Experimental data, however, do not substantiate this theory.

Results obtained at the Kansas station agree with those secured by

Montgomery and by Williams. The ears planted in the ear-to-row tests included in Table 1 were divided into three groups according to the degree of indentation. Group I includes the ears that were sufficiently indented to be considered very rough. The crowns of the kernels tended to be chaffy. Group II was composed of ears that were well indented but were intermediate between the rough and the smooth dented types. Group III included ears that were well dented but not to such an extend as to cause a rough type of ear. All smooth dented ears and many that classed as "wrinkled dent" were included in this group. In Table 6 it will be noted that the rough type of ears consistently produced lower yields than did the smooth type, and that with the majority of the varieties the intermediate indented ears outyielded those with the rougher indentation.

Table 6.—*Yields from seed ears with very rough, medium rough, and smooth and wrinkled dent types of indentation.*

Variety.	Type of indentation.					
	Very rough.		Medium rough.		Smooth and wrinkled dent.	
	Number of ears.	Yield per acre.	Number of ears.	Yield per acre.	Number of ears.	Yield per acre.
		Bushels.		*Bushels.*		*Bushels.*
Boone County White	142	42.99	183	49.89	64	47.64
Hildreth Yellow Dent	40	62.69	77	61.68	72	64.88
Reid Yellow Dent	69	61.70	94	65.13	120	67.42
Hogue Yellow Dent	14	36.39	38	38.16	10	40.41
Kansas Sunflower	32	43.67	131	43.18	37	45.91
Legal Tender	18	48.42	40	52.46	21	52.73
McAuley White Dent	17	51.17	34	55.10	41	57.40
Pride of Saline	5	35.41	21	40.03	22	40.90
Total or average yield	327	49.22	576	52.59	343	53.46

Percentage of Grain as Related to Yield.

Ear corn that will shell out a high percentage of grain to cob is more desirable from the standpoint of the feeder who is buying corn than that which shells out a comparatively low percentage. The popular opinion, however, that "high percent grain to cob" corn is superior to "low percent grain to cob" corn for production purposes does not agree with experimental data.

Data regarding the relation of proportion of grain to cob was available in only a few of the ear-to-row tests conducted on the Kansas station. The ears were divided into four groups according to the proportion of grain to cob. Those ears having respectively 82 to 83, 84 to 85, 86 to 87 and 88 to 89 percent of grain were divided into as many groups. The yields obtained from these groups are given in Table 7. They indicate that within certain limits at least there is no relation between the percentage of grain to cob and the yield.

TABLE 7.—*Yields from seed ears having various proportions of grain to cob.*

Percentage of grain on the ear.	Number of ears.	Average yield per acre in bushels.
82 to 83	98	50.77
84 to 85	168	49.78
86 to 87	126	49.87
88 to 89	88	49.58

NUMBER OF ROWS AS RELATED TO YIELD.

The number of rows of kernels per ear is a character that does not receive a great deal of attention. This character is evidently considered somewhat arbitrary as the score card standards allow for a range of four to six rows. The number of rows per ear naturally varies with the variety. Small, early corn has fewer rows than the large, late maturing varieties. The average yields from seed ears of different varieties having 16, 18, 20, and 22 rows are given in Table 8.

TABLE 8.—*Average yields from seed ears of different varieties of corn with 16, 18, 20, and 22 rows.*

Variety.	Number of rows per ear.							
	16		18		20		22	
	Number of ears.	Average yield per acre.	Number of ears.	Average yield per acre.	Number of ears.	Average yield per acre.	Number of ears.	Average yield per acre.
		Bushels.		*Bushels.*		*Bushels.*		*Bushels.*
Boone County White	87	42.02	114	38.48	44	37.13		
Kansas Sunflower	43	55.27	76	43.16	20	41.78		
Leaming	10	41.76	13	37.34	7	36.25		
Legal Tender	9	44.78	30	51.73	41	49.27		
Hogue Yellow Dent	29	33.93	38	36.41	19	34.91		
Average or total	178	43.55	271	41.43	131	39.87		
Hildreth Yellow Dent	...	...	67	63.36	122	63.14	35	60.52
Reid Yellow Dent	...	...	41	55.25	94	59.80	44	59.29
Average or total	...	...	108	59.31	216	61.47	79	59.91

In Table 8 it will be noted that for the Boone County White, Kansas Sunflower, Hildreth, and Leaming varieties the ears with the least number of rows produced the highest average yields, while for the Reid, Hogue, and Legal Tender varieties the intermediate group of ears produced the best. The latter varieties are comparatively early maturing ones which have characteristic narrow kernels as compared with the first four varieties. This may or may not be significant. The indications are that ears with the largest number of rows are not the best producers, and that for eastern Kansas conditions ears with 16 or 18 rows of kernels are likely to outyield those with a larger number.

Conclusions.

The data available indicate that certain ear characters have been given more consideration than their worth as related to yield warrants, while other characters have been emphasized that may actually tend to decrease the yields. Many more data relative to the relation of ear characters to yield are needed, especially regarding those characters whose correlation with yielding capacity might vary according to conditions of soil and climate. It is a well-known fact that under Kansas conditions comparatively smooth types of corn produce better under adverse conditions than the roughly indented types. It is also well known that deep kerneled varieties do not produce as well on thin upland soils as the more shallow grained varieties. In western Kansas where moisture is usually the limiting factor in growth, comparatively smooth, shallow kerneled varieties of corn produce best. Evidently, certain ear characters that are associated with high yields under favorable conditions for corn may or may not be correlated with maximum production under comparatively poor conditions for this crop.

CONTRIBUTIONS TO AGRONOMIC TERMINOLOGY—2.

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INTRODUCTION.

Agronomists have been concerned chiefly with what crop plants will do under different environments. There is need for more knowledge of (1) how they are built, both in general structure (morphology) and in minute detail (histology), and (2) how they function (physiology). With such knowledge will come a better understanding of what they do; that is, how they react to environment (ecology), which is the present agronomic aim.

Agronomists have not always been careful in the use of what they commonly speak of as botanical terms. If the crop plant and its environment are the study of the agronomist, then these terms are no more botanical than agronomic or horticultural. All will agree that such terms should not be avoided but selected in preference to terms of broad, general meaning which may give rise to vague or inaccurate conceptions.

This paper and the next, the second and third in the projected series, are devoted to terms denoting the different parts of crop plants. They consist, therefore, almost wholly of definitions of nouns. Verbs are included only when a given noun has a verbal form. It is proposed to devote the fourth paper to descriptive adjectives.

PLANTS.

plant, *n.* Any organism belonging to the vegetable kingdom; a vegetable, in the broad sense. Plants are distinguishable from animals, for the most part, by one or more of the following characteristics: Cell walls composed of cellulose; presence of chlorophyll; absence of a pulsating vacuole; and, in general, by lack of voluntary motion and conspicuous irritability.

plantlet, *n.* A little plant; a young plant.

cutling, *n.* (*new.* C. R. B.) 1. The juvenile stage of any plant growing from a detached vegetative portion of a plant, either a stem, as in potato and sugar cane, or a root, as in sweet potato. The last is properly called a rootling, which see. 2. Any plant derived from a detached vegetative part of a plant, in contrast to seedling.

cuttage, *n.* The propagation of plants by means of slips or cuttings.

cutting, *n.* 1. A slip or shoot from a growing plant, to be rooted for vegetative reproduction. 2. A part of a dormant shoot, or of a tuber or root, to be used for vegetative reproduction, as in sugar cane, potato, and sweet potato.

rootling, *n.* (*new.* C. R. B.) 1. The juvenile stage of a plant grown from a root-cutting, as in the sweet potato. 2. Any plant grown from a root-cutting, in contrast to a seedling or cutling.

seedling, *n.* 1. The juvenile stage of a plant growing from a seed. 2. In plant breeding, any plant derived from seed, in contrast to a plant vegetatively produced.

set, *n.* A young plant ready for setting; a seedling, slip or cutting ready for planting.

slip, *n.* A cutting, shoot, leaf, or portion of a shoot or leaf from a growing plant, to be rooted for vegetative reproduction.

member, *n.* Any morphologically distinguishable part of a plant, as a root, a stem, a leaf.

organ, *n.* A member or structure of a plant adapted to perform some specific function or functions, as a green leaf for photosynthesis, a seed for reproduction, etc.

annual, *n.* A plant persisting for only a single season.

winter annual. An annual which starts growth in the fall, or at the opening of a winter rainy season, and matures in the following spring or early summer.

biennial, *n.* A plant which produces only vegetative growth the first season, remains dormant during the winter and produces flowers and fruit in the second season, as the turnip, beet, carrot, and sweet clover.

perennial, *n.* A plant which persists for more than two years, including herbaceous perennials, like clover, alfalfa, and Johnson-grass, in which the aerial stems die at the end of the season and only the crowns or rootstocks survive, and shrubs and trees, in which the woody parts above ground also survive.

Roots.

root, *n.* That part of the plant, usually subterranean, which lacks nodes, which bears neither leaves nor flowers, and which functions for one or more of the following purposes: Absorption, aeration, storage, and anchorage. It is usually tipped with a root-cap.

primary root. 1. The root which first appears at the tip of the hypocotyl. 2. A main root.

secondary root. 1. A root arising from any other part of the stem than the tip of the hypocotyl. 2. A branch or division of a primary root.

coronal root. A root arising from the crown of a plant.

seminal root. A root arising from the tip of the hypocotyl.

aerial root. A root springing from some part of the stem above ground.

fibrous root. A slender thread-like root. The sort commonly produced by grasses.

fleshy root. The thickened root of such plants as carrot, beet, sweet potato, etc., used for storage.

root, *v. i.* To purchase roots; to anchor by means of roots.

root, *v. t.* To cause or allow roots to form, as to root a cutting.

air-root, *n.* See aerial root.

brace-root, *n.* An aerial root which functions in part to brace the erect stem. Very abundant on maize.

rootage, *n.* 1. The act of taking root; the state of being rooted. 2. The aggregate or total roots of a plant. 3. Roots, tubers, bulbs, or other underground parts of plants, collectively.

rootcap, *n.* A mass of cells inclosing and protecting the growing point of a root, and sloughing off at the outer surface.

roothair, *n.* A tiny hair-like protrusion of an epidermal cell near the growing tip of a young root.

rootlet, *n.* A small root. This term is applied to the finer divisions of a root system.

taproot, *n.* A single central root, either fleshy as in carrots, beets, etc., or woody as in oaks.

SHOOTS AND BUDS.

SHOOTS.

shoot, *n.* 1. A stem with its attached members, in contrast to a root. (A plant consists of root and shoot.) 2. A rapidly growing or vigorous young branch, sucker, or tiller.

shoot, *v. i.* 1. To produce shoots. 2. To put forth, to grow rapidly, to burst forth, as leaves, flowers, or shoots.

offset, *n.* A short lateral branch that roots at the tip and produces a new shoot, as in the house-leek.

sprout, *n.* A young shoot.

sprout, *v. t.* To cause to put forth sprouts, as to sprout seeds. See *desprout.*

sprout, *v. i.* To produce sprouts.

desprout, *v. t.* (*new.* C. R. B.) To remove sprouts from, to divest of sprouts, as to desprout potatoes. The use of the verb sprout in this sense is unfortunate and should be avoided. (Compare desucker and detiller, detassel, etc., also dehorn.)

sucker, *n.* 1. A shoot produced from the crown or base of any of the taller, stouter grasses, as maize and sorghum, and of other large plants, including trees. 2. A shoot or daughter plant growing from a rootstock or root and hence often distant from the mother plant, as in Johnson-grass; Bermuda-grass, Canada thistle, yarrow, etc.

sucker, *v. i.* To produce suckers.

desucker, *v. t.* (*new.* C. R. B.) To divest of suckers, to remove suckers, as to desucker corn or sorghum. The use of the word sucker as a transitive verb meaning to remove suckers, is incorrect and undesirable, as are many other words of the same kind. (Compare desprout, detiller, detassel, dehorn, etc.)

tiller, *n.* An erect shoot or sucker from the crown of a grass, especially a small grain. Not exactly synonymous with sucker, which see.

tiller, *v. i.* To produce tillers.

detiller, *v. t.* (*new.* C. R. B.) To divest of tillers; to remove tillers from, as to detiller wheat.

graft, *n.* 1. A scion inserted in the stock. 2. The branch or portion of a plant growing from the union of scion and stock, or the graft.

graft, *v. t.* To insert a scion in the stem of another plant; to propagate by the insertion of scions.

graft, *v. i.* To insert scions from one plant into another; to practice grafting.

grafting, *n.* The act or process of inserting grafts.

scion, *n.* A piece cut from a shoot or twig for grafting into another plant.

stool, *n.* The aggregate of a main stem or shoot with all its attached tillers, suckers, or offsets, as a stool of wheat or milo. The use of stool, either as a noun or verb, in the sense of tiller or sucker is not recommended.

Buds.

bud, *n.* An undeveloped folial or floral stem or branch, usually inclosed in scale-like leaves; a shoot in the dormant or undeveloped state.

flower-bud. A bud which will produce a flower or an inflorescence; a floral bud.

leaf-bud. A bud which will produce a branch, usually leafy; a folial bud.

bud, *v. t.* To graft or propagate by inserting buds into slits in the bark of the stock.

bud, *v. i.* To produce or put forth buds.

bud-scale, *n.* One of the scales, either undeveloped leaves or modified stipules, which inclose a bud.

bulb, *n.* A spheroidal or ovoid leaf-bud, usually subterranean, composed of a cluster of thickened or fleshy scale-like leaves on a very short stem, as in lily, onion, etc.

scaly bulb. A bulb with comparatively narrow scales, as in the lily.

coated bulb. A bulb with broad, concentrically enwrapping scales, as in the onion.

STEMS AND BRANCHES.

stem, *n.* The axis of a shoot; the part which bears the other members, such as roots, branches, foliage, and inflorescence. Different types of stems have special names, as culm, haulm, cane, and trunk. Modified forms of stems also have special names, which are defined herein.

stalk, *n.* A stem. Usually applied to tall-growing annual plants and then used in compound form, as cornstalk.

stock, *n.* 1. A stem or stalk; a large, stout stem; a trunk. 2. The stem or branch into which a scion is inserted in grafting.

bole, *n.* The trunk or stem of a tree.

branch, *n.* A subdivision of a stem or root; a secondary stem.

cane, *n.* A tall, or long, and slender stem; the name usually applied to the stems of such tall, slender grasses as sorghums, sugar cane, etc., and in horticulture to the slender stems of blackberries, raspberries, etc. 2. The tall grasses which form the canebrakes of the Southern States, two species of *Arundinaria,* of which the smaller (*A. tecta*) is called *switch-cane.* 3. Sugarcane as a crop. The sorgos (sweet or saccharine sorghums) are popularly but wrongly called "cane" and "sugar-cane."

caudex, *n.* 1. The persistent basal portion of the stem of a perennial herbaceous plant, as in alfalfa; a crown. 2. The stem or trunk of a palm or tree-fern.

caulome, *n.* Any member of a plant, which morphologically is a shoot.

cladophyll, *n.* A leaf-like branch. It may be distinguished from a folial leaf by its position in the axil of a leaf or bract, and frequently by its bearing buds or flowers; a phylloclade.

corm, *n.* The enlarged, fleshy base of a stem, resembling a bulb in form, but solid.

culm, *n.* The cylindrical or somewhat compressed, jointed, usually hollow, aerial stem of grasses.

crown, *n.* 1. The basal portion of a stem, especially if thickened; the point of attachment of the primary and secondary roots. 2. The spreading portion or top of a tree or shrub.

haulm, *n.* A stem, especially of a herbaceous plant, as bean, clover, potato, etc.

internode, *n.* The portion of a culm between two nodes.

limb, *n.* A division of a stem; a branch. Specifically, the third ramification of a tree, the first and second being trunk and branch, respectively, and twig the fourth. Used for the branches of some of the larger, much-branched field crops, as cotton, castor bean, etc. The terminology of the four divisions named can be applied to crop plants if desired except that stem is preferred to trunk in herbaceous plants.

node, *n.* The joint of a stem; the plane of a stem marked by the place which normally bears a leaf or whorl of leaves.

phylloclade, *n.* A cladophyll. Phylloclade is the correct but less used form of the word.

rhizome, *n.* A rootstock.

rootstock, *n.* A creeping underground stem, often fleshy, the leaves reduced to scales. Familiar examples occur in quack-grass, Johnson-grass, and many other grasses. Particular kinds of rootstocks have received special names, as tuber, which see.

runner, *n.* A slender stolon, as in the strawberry.

stolon, *n.* An above-ground, usually prostrate, stem or branch which tends to root. Bermuda-grass, crabgrass, and similar grasses, as well as white clover, furnish good examples.

tendril, *n.* A stem modified for climbing or anchorage, as in melons and the grape, or a modified leaflet, as in the pea and vetch.

thorn, *n.* A sharp-pointed process formed by a reduced or degenerate, indurated, leafless branch, as in the locust. A spine is a similar process resulting from a degenerate leaf, while a prickle is an outgrowth from the epidermis.

trunk, *n.* The main stem or axis of a tree; a bole. See also caudex 2.

tuber, *n.* A very much thickened rootstock, functioning for storage, as in the potato, artichoke, etc.

twig, *n.* A small limb or branch; the fourth division or degree in the branching of a tree, the first, second, and third being trunk, branch, and limb, respectively.

Leaves.

leaf, *n.* A lateral, usually flattened and expanded, member of determinate growth, borne at a node and containing vascular tissue. Ordinary folial leaves contain green coloring matter (chlorophyll), have stomata on one or both surfaces, and subtend buds situated in their axils. A typical folial leaf consists of blade or lamina, stalk or petiole, and a pair of appendages (stipules) at the base of the petiole. Modified leaves include scales, spines, tendrils, pitchers, and all the part of the flower.

simple leaf. A leaf having an unjointed petiole and a single blade, as in most crop plants.

compound leaf. A leaf usually composed of two or more leaflets, each with its own jointed petiole, as in most legumes; for example, clover, bean, pea, cowpea, soy bean, etc.

leaf, *v. i.* To produce leaves, to put forth leaves; to leave.

leave, *v. i.* To leaf, to put forth leaves.

leafage, *n.* Foliage; leaves in general.

leafblade, *n.* See blade.

leaflet, *n.* One of the divisions of a compound leaf; literally, a little leaf.

leafstalk, *n.* See petiole.

auricle, *n.* An ear-shaped appendage, as the pointed projection from the angles at the base of the blade or from the upper corners of the sheath in some grasses, etc.

blade, *n.* The expanded, usually flattened portion of a leaf; the lamina.

boot, *n.* The often inflated sheath of the upper leaf on the flowering stems of grasses, which incloses the inflorescence before flowering. When the inflorescence is swelling within the boot, preparatory to emerging, the crop is said to be "in boot" or in the boot stage.

cataphyll, *n.* Any reduced or undeveloped scale-like leaf which precedes the folial leaves, as a bud-scale.

collar, *n.* 1. The line of junction between root and shoot. 2. The line of junction between blade and sheath, in the grass leaf.

foliage, *n.* Leaves in general; leafage.

foliation, *n.* The act of leafing; putting forth leaves.

foliole, *n.* A leaflet; one division of a compound or divided leaf.

lamina, *n.* The blade of a leaf; a leafblade.

ocrea, *n.* A sheath; specifically one formed by 2 stipules, more or less united into a tube, as in buckwheat and other members of the Polygonaceae.

petiole, *n.* The leafstalk, or narrow stem-like portion of a leaf, by which it is attached to a stem. A leaf without a petiole is said to be *sessile*.

petiolule, *n.* The petiole of a leaflet in a compound leaf; literally, a little petiole.

phyllode, *n.* A somewhat dilated petiole having the appearance and function of a blade, as in some Acacias.

phyllome, *n.* Any member of a plant which morphologically is a leaf.

phyllotaxis or **phyllotaxy,** *n.* The arrangement of leaves on a stem.

prefoliation, *n.* The method of disposition of nascent leaves within a bud; vernation.

scale, *n.* A reduced or rudimentary folial leaf or stipule, as on rootstocks, etc.; a budscale; a cataphyll.

sheath, *n.* The tubular petiole of a grass leaf, commonly inclosing the culm.

spine, *n.* A sharp-pointed process, resulting from an indurated, reduced or degenerate leaf, as in the barberry.

stipel, *n.* A stipule at the base of the petiolule of a leaflet.

stipule, *n.* A foliar appendage, one of a pair, sometimes united (see ocrea), borne at the base of a petiole in many plants. Usually membranous, but sometimes modified into spines or tendrils.

vernation, *n.* The method of disposition of the nascent leaves within a bud; prefoliation.

Epidermal Appendages.

hair, *n.* A member or appendage developed entirely from an epidermal cell and consisting of a single cell or a row, plate, or mass of cells; a trichome.

prickle, *n.* An indurated, sharp-pointed trichome, as on the rose, blackberry, horse nettle, buffalo bur, etc.

pubescence, *n.* 1. A covering or growth of fine, soft hairs or down. 2. Hairiness or downiness.

scale, *n.* 1. A flat, plate-like trichome; a squame. 2. A reduced or rudimentary leaf, or stipule, as a bud-scale; a cataphyll.

scurf, *n.* A membranous covering of squames.

squame, *n.* (*partly new.* B. and P.) A scale-like or plate-like trichome, such as compose scurf, as on the goosefoot, lamb's-quarter, or pigweed, and the buffalo berry, etc.

trichome, *n.* Any appendage of a plant that is morphologically a hair.

AGRONOMIC AFFAIRS.

MEETINGS OF THE SOCIETY.

The annual meeting of the American Society of Agronomy will be held in Washington, D. C., November 13 and 14, 1916. On the three following days, November 15 to 17, will be held the meeting of the Association of American Agricultural Colleges and Experiment Stations. Numerous other meetings of agricultural organizations will be held at about the same time. These will include the Society for the Promotion of Agricultural Science and the American Farm-Management Association, with which, in accordance with the custom of previous years, it is probable that the American Society of Agronomy will hold one or more joint sessions.

The Great Plains Cooperative Association will meet at Amarillo, Texas, August 22–24, 1916. As usual, a sectional meeting of the American Society of Agronomy will be held jointly with this association. Members of the Society in the Great Plains are urged to attend this meeting, where special attention will be given to the problems of agronomists in this semiarid area.

Titles for papers to be presented at either of these meetings may be sent to the secretary at any time. It is especially requested that titles for papers for presentation at the Amarillo meeting be submitted promptly, so that the program may be arranged and printed some time in advance of the meeting.

MEMBERSHIP CHANGES.

The membership reported in the March–April JOURNAL was 566. Since that time, 3 members have resigned and 26 have allowed their memberships to lapse. In the same period, 25 new members have been added, so that the net loss since the last report is 4. The total membership of the Society on this date is 562 and the total number of new members recorded in 1916 is 122. The names and addresses of the new members, the names of members resigned and lapsed, and the recent changes of address are as follows:

NEW MEMBERS.

ALVORD, EMORY D., Experiment Station, Pullman, Wash.
BLAIR, R. E., Yuma Experiment Farm, Bard, Cal.
BRUCE, O. C., Hyattsville, Md.
BURNETT, GROVER, 79 West Third St., Logan, Utah.
GILKERSON, H. C., 216 Agricultural Bldg., Champaign, Ill.

Gish, N. A., Kansas State Agr. College, Manhattan, Kans.
Hearn, W. E., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Justin, M. M., 1212 Fremont St., Manhattan, Kans.
Laidlaw, C. M., Physics Dept., Ontario Agr. College, Guelph, Ontario.
Lyness, W. E., Akron Field Station, Akron, Colo.
McLane, J. W., 731 West Sixth St., Riverside, Cal.
Maris, Edwin I., Kansas State Agr. College, Manhattan, Kans.
Miles, F. C., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Palmer, H. Wayne, 67 West Tenth Ave., Columbus, Ohio.
Paxman, J. W., Nephi, Utah.
Quigley, J. V., Kansas State Agr. College, Manhattan, Kans.
Reppert, R. R., Kansas State Agr. College, Manhattan, Kans.
Shick, G. M., Kansas State Agr. College, Manhattan, Kans.
Scott, Herschel, Kansas State Agr. College, Manhattan, Kans.
Sewell, M. C., Kansas State Agr. College, Manhattan, Kans.
Stewart, Rupert L., College of Agr., State College, N. Mex.
Towle, R. S., Edgeley Substation, Edgeley, N. Dak.
Townsend, C. O., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Truog, Emil, Agr. Expt. Station, Madison, Wis.
Zahnley, J. W., Kansas State Agr. College, Manhattan, Kans.

Members Resigned.

Ernest DeTurk,
E. A. Lods.

Members Lapsed.

Wilbur M. Ball,
Robert L. Ballard,
Albert E. Bowman,
John Buchanan,
Frank K. Cameron,
Hugh Critz,
W. Frank Dobbs,
T. R. Douglass,
J. F. Eastman,
A. R. Evans,
S. W. Fletcher,
O. J. Grace,
C. J. Grant,
F. W. Johnson,
F. C. Kaden,
R. A. Kinniard,
William Krechov,
E. R. Lloyd,
Irwin Oakland,
Newell S. Robb,
H. F. Roberts,
A. D. Robertson,
S. H. Starr,
J. W. White,
J. G. Willier,
Chas. S. Wright.

Changed Addresses.

McKee, Roland, Chico, Cal.
Mackie, W. W., 2525 Durant Ave., Berkeley, Cal.
Millar, C. E., Dept. of Soils, Michigan Agr. College, East Lansing, Mich.
Peacock, Walter M., Stockbridge Hall, Mass. Agr. College, Amherst, Mass.
Suddath, R. O., Epworth, Ga.
Waldron, L. R., Agricultural College, N. Dak.

NOTES AND NEWS.

The departments of experimental and instructional agronomy in the Nebraska station and college have been consolidated, and W. W. Burr has been elected to take charge of the new department of agronomy, effective July 1. Mr. Burr was for several years in charge of the cooperative experiments in dry-land agriculture conducted at North Platte, Nebr., by the Nebraska station and the U. S. Department of Agriculture, and for the past four years has been a traveling inspector of the experimental work of the Federal office of dry-land agriculture.

D. H. Hill, president of the North Carolina Agricultural College for the past 26 years, has resigned to write a history of the state of North Carolina. His successor will be appointed at the June meeting of the board of trustees.

Wallace Macfarlane has been appointed assistant agronomist in charge of the soils work of the Oklahoma station.

A. G. McCall, professor of agronomy in the State University of Ohio, has resigned, effective at the close of the college year. At that time he will take charge of the soil investigation work of the Maryland station.

The editor has been requested to state that the two articles relative to sugar beets which appeared in the March–April number of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY were based on work which was not conducted under the direction of the Office of Sugar-Beet Investigations, U. S. Department of Agriculture, and that that office is not responsible for the publication of these articles.

J. G. Lipman, director of the New Jersey station, is editor-in-chief of *Soil Science,* a monthly journal published under the auspices of Rutgers College, the first number of which appeared in January, 1916. Associated with him is a board of twenty-three consulting editors, the membership of which includes many of the best-known soil scientists in Europe and America. It is the plan to make the journal international in scope, limiting it to soil problems, including soil biology, soil physics, and soil chemistry.

Under date of March, 1916, the H. W. Wilson Company, White Plains, N. Y., have issued the first number of the *Agricultural Index,* which is to be published in March, May, July, November, and January. It is planned to include in this index the more important agricultural periodicals, both scientific and popular. The publications of the U. S. Department of Agriculture and of the State experiment stations will also be included. It is planned to make the *Index* a ready-reference guide to the most valuable current agricultural literature.

HUNDRED-BUSHEL CORN CLUB.

J. D. Harper, assistant in agricultural extension at Purdue University, sends the following interesting note on a phase of the extension work in agronomy conducted by that institution:

> During the past two years the Indiana Corn Growers' Association, in coöperation with the Agricultural Extension Department of Purdue University, has offered a gold medal watch fob to any farmer who would grow 100 bushels of corn per acre on 5 or more acres. Twenty-two men have qualified for membership in this club. The summer of 1914 was a better corn season in Indiana than was 1915, as is evident from the fact that out of 238 contestants in 1914, there were twenty-one 100-bushel men, while in 1915, with 408 aspirants, but one produced a yield of 100 bushels per acre on his 5-acre tract.
>
> A most important factor in the demonstration has been the item on cost of production. Reliable figures show that on the average it costs $13.49 per acre to grow corn in Indiana. With an average yield for ten years of 36.4 bushels per acre for the state, the cost of producing a bushel of corn amounts to 37.1 cents. The average yield of the men in the 100-bushel club is 104.2 bushels per acre. The average cost per acre is $19.06, or a cost per bushel of 18.2 cents. These figures show that by increasing the yield to 100 bushels per acre, the cost of production per bushel has been reduced one half.

MEETINGS OF LOCAL SECTIONS.

The twelfth regular meeting of the Washington (D. C.) section of the American Society of Agronomy was held at the Cosmos Club on February 25, 1916, with an attendance of 25 members and 8 guests.

C. H. Kyle discussed "The Relationship of Early Growth and the Yields of Grain in Corn." In the discussion it was shown that a vigorous early growth is correlated with large yields of grain. It was also shown that by selecting the best ears from thick plantings, which were presumably produced on plants making a vigorous early growth, it might be possible to increase the yields.

W. W. Stockberger presented a paper on the "Relative Precision of Current Formulæ for Calculating Normal Yields of Test Plots," in which he used the hop crop to show the unreliability of experimental data when using various mathematical formulæ in interpreting crop yields. He also showed that the common check system did not overcome error, but that accuracy was measurably increased by replication. This paper is included in the current issue of the JOURNAL OF AGRONOMY.

J. S. Cole, in his talk on "Seven Years Soil Moisture Records at Williston Substation, N. Dak.," showed that water penetrates only beyond the point of saturation, and that the moisture contained in a saturated soil is not sufficient to carry the crop through to maturity without additional rains during the growing season.

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THE MODE OF POLLINATION IN SOME FARM CROPS.[1]

M. N. POPE,

ST. PAUL, MINNESOTA.

INTRODUCTION.

The work of the agronomist is fundamental to the development of agriculture. He it is who studies the soil in its physical and chemical relations and the farm crop plant in its response to the environmental conditions of soil and climate within which it lives. He must obtain the variety, best in quality and yield, which is suitable for those conditions. This may be done through the testing of varieties already existing in the locality, through the introduction of varieties from other parts of the world, or by the improvement of existing varieties through plant breeding. After the sorts are found best suited to the grower's use, the seed must be multiplied and finally distributed to the grower.

In a large part of this work the nature of the pollination process is very important. If different varieties of a cross-pollinated plant are grown side by side, the purity of the seed is destroyed and the yield of subsequent generations may be temporarily affected. Introductions of so-called "varieties" may consist largely of hybrid stock. Many of these splitting forms may be undesirable and the whole introduction can with difficulty be compared with the local crop. Besides this, the introduced form is likely to cross with the local variety and the effect of a good introduction is delayed or lost.

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[1] A review of the literature on the mode of pollination of the more important grain crops. Received for publication March 22, 1916.

It is obvious that any cross-fertilized plant must be heterozygous. We can no more expect all plants of such a type in a neighborhood to have the same gametic composition than we can expect to find all men on an isolated island exactly alike in all hereditary characters. Upon such plants, the power of selection is very marked. The heterozygous characters will at once begin to split up into stable forms. For a few generations, selection of such good stable forms is remarkably effectual as an ameliorative agent. This, however, is not a good argument in favor of the theory that evolution proceeds by the addition of small variations. Cross-fertilization, of course, perpetuates the heterozygous condition and consequently demands constant care in the continued selection of the best types for use. The effect of such selection is gradually to eliminate the less desirable forms from the progeny but, as a rule, cross-fertilized plants demand a certain amount of out-crossing to retain their natural vigor.

The effects of self-fertilization upon a normally cross-fertilized plant is sufficiently interesting to be noted here. In the work of the great majority of investigators mention is made of decreased yield and vigor and increased degeneracy when maize is self-fertilized as a means of obtaining individuals homozygous for certain characters. Many other investigators on other cross-fertilized species have observed the same phenomena, as well as those of increased vigor and yield, from hybridizing non-related individuals, or, as Darwin has it, plants differing "in general constitution." Kölreuter (1763)[2] noted the increased vigor and various nice adaptations for cross-pollination in cross-fertilized plants. Gärtner (1849) noted the luxuriance of hybrids shown in the increased growth and development of root shoots, branches, leaves, and blossoms, and especially in the extraordinary length of stems. He agreed with Kölreuter that "the vigor of a plant can even serve to indicate its hybrid nature in a doubtful case." Kölreuter (1763) suggested that this increased vigor was due to the fact that the energy of the plant was not exhausted by the production of seed. Gärtner, however, proved the fallacy of this notion by showing that (1) such luxuriance does not always exist among diœcious plants; (2) the luxuriance is always present and visible before the flowers are produced; (3) not all partially fertile and sterile hybrids have this increased vegetative power; (4) the hybrids showing greatest luxuriance also showed greatest fertility; and (5) though the fruit and seed production is increased by planting partially fertile hybrids thickly enough to limit the vegetative growth, the sterile plants are never made fertile by this method.

[2] Names and dates refer to literature cited at the end of the paper.

Darwin was fully convinced that "nature abhors perpetual self-fertilization" and wrote his "Cross and Self-fertilization in the Vegetable Kingdom" (1889) in support of this thesis, but he never failed to note evidence contrary to this belief. Consequently, we read that *Nicotiana tabacum* failed to live up to his idea of what should happen; and that he isolated in the third and fourth self-fertilized generations of *Mimulus luteus,* a strain which was taller and more fertile than the intercrossed plants during the fifth to seventh generations, though in the first four generations selfing seemed to be injurious to the parent plants. He also found that, by selfing plants of *Mimulus luteus, Ipomea purpurea, Dianthus caryophyllus,* and *Petunia violacea,* all of which varied greatly in the color of their flowers, he obtained, with no selection whatever, strains which possessed absolute or very nearly absolute uniformity of color. One of the most interesting of his "exceptions" was the plant of *Ipomea purpurea* which he named "Hero." This plant was remarkable for its fertility, peculiar color, and increased tallness, all of which characters it transmitted to its offspring for three generations, the last being the ninth which had been self-fertilized. Furthermore, the intercrossed grandchildren of Hero were shorter than the self-fertilized grandchildren. He remarks that "we see here that the mere act of crossing two distinct plants does not by itself benefit the offspring." Darwin was much puzzled by the families of naturally self-fertilized plants like some of the Leguminosæ, but from the evidence he had gathered he concluded that they were but exceptions to the general rule that cross-fertilization was necessary for the continued existence of a plant species.

Focke (1881) noted that hybrids between markedly different species are frequently quite delicate, while those between species or races more nearly related are generally larger, show more rapid growth, more blooms, earlier flowering, longer duration of life, increased size of individual organs, and a greater capacity for asexual propagation.

The exceptional cases mentioned above in Darwin's work probably would not have puzzled him had he known of Mendel's researches, since all of them are easily explainable when we accept Mendel's epoch-making law. Since 1905, East, Hayes, and Shull have done a great deal of work on maize and tobacco which, in the light of Mendel's law, has cleared the atmosphere remarkably.

Shull (1910) gives as conclusions to his work up to 1910 the following statements:

> 1. The progeny of every self-fertilized corn plant is of inferior size, vigor, and productiveness as compared with the progeny of a normally cross-bred

plant derived from the same source. This is true when the chosen parent is above the average condition as well as when below it.

2. The decrease in size and vigor which accompanies self-fertilization is the greatest in the first generation and becomes less and less in each succeeding generation until a condition is reached in which there is (presumably) no more loss of vigor.

3. Self-fertilized families from a common origin differ from one another in definite hereditary morphological characters.

4. Regression of fluctuating characters has been observed to take place away from the common mean or average of the several families instead of toward it.

5. A cross between sibs within a self-fertilized family shows little or no improvement over self-fertilization in the same family.

6. A cross between plants belonging to two self-fertilized families results in a progeny of as great vigor, size, and productiveness as are possessed by families which had never been self-fertilized.

7. The reciprocal crosses between two distinct self-fertilized families are equal and possess the characters of the original corn with which the experiments were started.

8. The F_1 generation from the combination of plants belonging to certain self-fertilized families produces a yield superior to that of the original crossbred stock.

9. The yield and quality of the crop produced are functions of the particular combination of self-fertilized parental types and these qualities remain the same whenever the cross is repeated.

10. The F_1 hybrids are no more variable than the pure strains which enter into them.

11. The F_2 shows much greater variability than the F_1.

12. The yield per acre of the F_2 is less than that of the F_1.

Corollary a.—When two plants of the same self-fertilized family or within the same genotype, however distantly the chosen individuals may be related, are bred together, there will be no increase of vigor over that shown by self-fertilized plants in the same genotype, since no new hereditary element is introduced by such a cross.

Corollary b.—First generation hybrids produced by crossing individuals belonging to two self-fertilized lines of pure genotypes will show the highest degree of vigor possible in progenies representing combinations of these two genotypes, because in the first generation every individual will be heterozygous with respect to all the characters which differentiate the two genotypes to which the chosen parents belong, while in subsequent generations recombinations of these characters will increase the average number of heterozygous genes present in each individual.

Corollary c.—Crosses between sibs among the first generation hybrids between two genotypes will yield progenies having the same characteristics, the same vigor, the same degree of heterogeneity, as will be shown by the progenies of self-fertilized plants belonging to the same first generation family.

East and Hayes (1912) believe it to be established that:

1. The decrease in vigor due to inbreeding naturally cross-fertilized species and the increase in vigor due to crossing naturally self-fertilized species are manifestations of one phenomenon. This phenomenon is heterozygosis.

Crossing produces heterozygosis in all characters by which the parent plants differ. Inbreeding tends to produce homozygosis automatically.

2. The phenomenon exists and is, in fact, widespread in the vegetable kingdom.
3. Inbreeding is not injurious in itself, but weak types kept in existence in a cross-fertilized species through heterozygosis may be isolated by this means. Weak types appear in self-fertilized species, but are eliminated because they must stand or fall by their own merits.

They also state as a rule, although some exceptions are noted:

> The greater the degree of heterozygous condition the greater is the vigor of the resulting plant.
>
> The poor strains that have had the help of hybridization with good strains, combined with the added vigor due to heterozygosity, are stripped of all pretense by selfing, shown in all their weakness, and inbreeding is given as the cause of their degeneracy.

They maintain that though there may be a slight loss of vegetative vigor in the case of plants, there is no degeneration, because there is no loss of constitutional vigor.

These conclusions are in accord with a large amount of experimental evidence and seem to the writer to be philosophically sound.

With the thought that plant breeders would welcome a review of the work done on the pollination of farm-crop plants, the present review was undertaken and was carried out at the Minnesota experiment station at the suggestion of H. K. Hayes. The writer is indebted to Mr. Hayes for many helpful suggestions.

MAIZE.

The maize plant (*Zea mays*) is monœcious, the male flowers being carried in a tassel at the tip of the stalk and the female flowers on a short branch generally about half way between the tassel and the ground. Exceptions may show female flowers and maturing kernels in the tassel or male flowers emerging with the silk from the ear. Such combination of male and female flowers are common in the terminal flower heads of suckers. The pollen ripens and begins to be shed one to three days before the silk emerges and continues about eight days. Crossing is therefore favored at first, though some selfing is probable later. Früwirth's (1909) experiments on pollination of corn show 24 percent setting in unenclosed plants a sufficient distance from other corn to prevent crossing. Knuth (1909) found on one stalk but 16 percent selfing in the older ear and 4 percent in the younger. It is likely that Früwirth's figures would be reduced under field conditions where free competition with foreign pollen is possible. Self-fertilization results in reduced yield. Halsted (1904) found that an increase of albinism, which East and Hayes (1911) show acts as a simple Mendelian recessive, and loss of vigor results from selfing sweet corn. Emerson (1912) and Jones (1915) later confirmed this observation. East (1907) found a reduced yield but extreme uniformity and nothing which could be called degeneration in plants selfed two and three generations.

Miss Lacy (1915), in determining the relative value of butt, middle, and tip kernels for seed, examined 81 reports of such experiments and concludes that the tip kernels produced better yielding plants. She explains this on the theory that the tip flowers send out their silks last, when there is a greater chance for cross-fertilization, the occurrence of which must be held accountable for the increased yield of the offspring.

The Illinois station has for years encouraged the use for seed of corn from detasselled rows on account of the certainty that it resulted from cross-fertilization. (Hopkins et al., 1905.)

WHEAT.

The envelop of the floret of wheat (*Triticum sativum*) consists of a keel-shaped flowering glume or lemma and an inner glume or palea. A cross-section view of these glumes would show the flowering glume as an inverted letter V with the sides enclosing the lateral edges of the palea. The palea is shaped like the letter W except that the middle angle is rounded and flattened. Within the cavity thus formed are contained the sexual organs, consisting of a two-branched, feathery stigma and three stamens. The anthers are really four cylindrical sacs grouped in pairs and the pairs connected by a mass of fleshy tissue. The wall of each cylinder is lined with a single layer of minute globular pollen grains (Hays and Boss, 1899). The anther is supported by a slender filament capable of rapid growth. The filament is attached to the fleshy connecting tissue below the middle of the anther. At the base of the glumes and so placed that an increase in its size spreads the two glumes apart, is a tiny sac-like organ called the lodicule. Hays and Boss (1899) say that the flowers open at dawn. Recent results obtained at the Minnesota station (unpublished) show some flowering during the day.

Both stamens and pistil are found in the wheat flower. The terminal position of the inflorescence facilitates the transference of pollen by the wind. The opening of the flower is caused by the absorption of water by the lodicules. These swell and force the glumes apart. (Kirchner says the tips may be separated 4 mm.) The filaments to which the anthers are attached elongate rapidly. In crossing wheat, the writer has seen these filaments in a spike used for the male parent grow a quarter of an inch in ten minutes. This elongation pushes the anthers up through the opening between the glumes. At the same time the anthers dehisce apically along the lines joining the cylinders into pairs and about one-third (Kirchner) of the pollen falls inside the flower. The anthers are afterward pushed completely outside the glumes, which close rapidly, leaving the anthers out (Carruthers, 1893). The rest of the pollen is scattered into the air and may be carried to other wheat plants by the wind. The pollen matures and the pistil becomes receptive at the same time, consequently selfing is the usual method of fertilization, though cross-pollination by the wind is possible. Rimpau has proved that cross-fertilization can occur (Früwirth, 1909) by emasculating the flowers and leaving them to mature freely in the open field. He obtained 59 percent seed setting.

Concerning natural cross-fertilization there is a considerable difference of opinion. De Vries (1906) says "wheat, barley, and oats are self-fertile and do not mix in the field through cross-pollination." Biffin (1905) says he has never met with a case of natural cross-fertilization. Saunders (1905) in 1903 at Ottawa noted an undoubted natural hybrid of wheat and thought it interesting enough to announce in the Proceedings of the American Breeders' Association. Howard, Howard and Rahman Kahn (1910), from a study of stray plants found in plots, each grown from the produce of single spikes, conclude that 231 cases of natural cross-fertilization were proved by them at Lyallpur, India.

Smith (1912) states that in the summer of 1908 a number of plants having awnless spikes were found growing in the breeding rows of Turkey wheat. This is a bearded variety and the rows had all been sown with great care from heads of the typical bearded Turkey wheat. The plants were placed in the rows in such a way that the investigators are convinced that they were actually the product of the seed sown and not accidental volunteers. Eight supposed hybrids were found in the 96 rows of the plot. The seed of each of these when tested in 1909 gave Mendelian segregation into bearded and non-bearded types. Other characters, such as color, length of spike, hairiness of glumes, etc., also segregated. Pure lines of these segregates gave results to be expected from hybrids.

Howard and Howard (1909) offer the following explanation of these divergent observations:

> The extent of this occurrence (natural cross-fertilization) seems to depend in India mainly on the irregular supply of moisture to the plant, combined with the great dryness of the air. It appeared to be exceedingly rare in non-irrigated districts. Often before the last irrigation the supply of water in the soil is so small that the plants partly wilt during the hottest part of the day, the glumes open and the stigmas are exposed to the air. . . . Experimental cultures might be protected from natural crossing by more frequent and even watering.

In the more humid northern countries, natural crossing is very rare. So rare is its occurrence that Früwirth (1909) states it as a rule that "wheat varieties can be cultivated side by side for years without spontaneous wheat crosses being observed." He quotes Rimpau as having cultivated on an average of 60 varieties (of *T. vulgare* only) side by side and observed by accurate plant-by-plant examination, only 17 cases in fifteen years in which spontaneous crossing could be admitted. Früwirth also quotes Hansen-Lyngby and H. Nilson of Svalöf as being of the opinion that

> in warm, good weather, forms which are considered as subject only to self-fertilization cross with one another more often, and Hansen observed, as did v. Kiessling, the occurrence of proven spontaneous crosses of wheat with spelt under such conditions.

According to Früwirth (1909) the following authorities say that self-pollination is by far the more prevalent but that cross-pollination is possible: Rimpau (for *T. vulgare, dicoccum,* and *spelta*), Körnicke (for *T. vulgare, durum, dicoccum,* and *spelta*), and Nowacki (for all the wheats). Rimpau and Körnicke hold that for *T. polonicum*, self-pollination is "more common" than is cross-pollination. Knuth says that pseudo-cleistogamous fertilization predominates, and that in many flowers of *T. polonicum* the anthers always remain within the glumes and are then apposed to the stigmas. The glumes do, however, diverge for a short time, but only to a distance of 2 mm. In *T. monococcum* the glumes diverge more widely than in common wheat and Körnicke concludes that here crossing is of more importance than selfing.

Nilsson-Ehle (1915) in 1911 sowed five rows of wheat with white hairy chaff, fairly dense ears, and white grain (Pudelweizen), and four rows of a white, lax-eared, red-grained type (Schwedischer Sammetweizen), each row alternating with a row of a local strain (No. 0728) characterized by hairless brown chaff, lax ear, and red grain. The flowering periods of the three types are almost the same. The rows were sown 6 inches apart, each containing 30 seeds 2 inches apart in the row. At harvest, the seed was gathered into four groups: (1) the rows of Pudelweizen, (2) the rows of 0728 alternating with Pudelweizen, (3) the rows of Sammetweizen, and (4) the rows of 0728 alternating with the Sammetweizen. The next season the seeds in these four groups were sown separately in rows 6 inches apart and 2 inches apart in the row and the hybrid plants counted. These showed ears with brown, hairy chaff since these characters are dominant over white, smooth chaff. What hybrids appeared were tested the following year and showed the expected segregation.

From 777 plants of Pudelweizen he obtained	7 brown, hairy hybrids.
From 610 plants of 0728 alternate with above	0 brown, hairy hybrids.
From 615 plants of Sammetweizen he obtained	3 brown, hairy hybrids.
From 611 plants of 0728 alternate with above	0 brown, hairy hybrids.

His results show that some plants of both Pudelweizen and Sammetweizen were fertilized by the pollen from Strain No. 0728, but that the latter showed no effects of cross-pollination. We may conclude, therefore, that different strains of wheat may vary considerably in their ability to be cross-fecundated.

Artificial hybrids between wheat and rye have been successfully made, but only where the wheat plant was the mother (Leighty, 1915). Leighty describes four cases of natural crossing of rye on wheat occurring in Virginia and Tennessee which he encountered in 1914. The existence of such hybrids indicates that the wheat flower is open to foreign pollen much more often than was formerly supposed to be the case.

OATS.

The spikelet of oats (*Avena sativa*) consists generally of from two to three perfect flowers. The parts of the flowers are quite similar to those of wheat except that the flowering glume is not keeled, the awn when present is attached to the back rather than to the tip of the flowering glume, and usually both the palea and the flowering glume remain enclosing the caryopsis after thrashing. The anthers and stigma mature simultaneously. As the flower opens, the antherial filaments elongate slowly and the anthers dehisce close to the stigma. Rimpau observed several times, according to Knuth (1909), that the anther walls suddenly contract, actively causing some of the pollen to be flung immediately upon the stigma. He would conclude, therefore, that self-fertilization is the usual process.

Kirchner (1886) states that anthesis begins in the afternoon under favorable weather conditions and lasts until evening. The process starts with the apical spikelet and proceeds to the base, the lower of the two flowers opening first. The flowers hang over and the anthers sway in front of the stigmas. If the anthers dehisce before the filaments finish elongating, self-pollination results, but if dehiscence occurs later, selfing is prevented. He concludes that "pollination takes place almost regularly within the flowers of the same panicle and rarely crossing, which occurs only in the small flowers at the top of the spikelet."

Hildebrand and Godron are of the opinion that crossing is favored and Appel believes that cross-pollination does take place to some extent (Knuth, 1909). The Experiment Station Record reports that Jamieson (1897) found that oat plants cross freely when grown side by side, the wind being effective as a pollen carrier.

Früwirth (1909) says that generally two of the stamens remain enclosed in the flowering glume, held there partly by the stigma and partly by the lateral edges of the glume. The dehiscence of the freely hanging anther may or may not cause selfing, but the two which remain close to the stigma shed their pollen at the same time or possibly a little later and selfing is almost certain to occur. From the structure of the flower and the method of blooming, he concludes that self-pollination is customary and leads to self-fertilization in flowers where one or two of the anthers remain entangled with the pistil. There is possibility of cross-pollination, however, where all the anthers hang down below the level of the stigma. In this case, crossing between flowers of the same panicle will be most likely, though the pollen from another plant may be brought by the wind. Früwirth (1909) further reports that Rimpau was able to detect a spontaneous cross five times in six years from nineteen varieties of oats cultivated side by side.

From these data it appears that although the possibility of crossing in oats is greater than in either wheat or barley, it very seldom does occur.

BARLEY.

In barley (*Hordeum sativum*) we have three spikelets at a node, each spikelet containing a single flower. In the two-rowed (*Hordeum sativum distichon*) only the middle row on either side of the rachis is fertile. The so-called four-rowed variety (*H. sat. vulgare*) is very similar to the six-rowed variety (*H. sat. hexastichon*). In the former the lateral rows overlap in such a way as to form a single row instead of two at each edge of the rachis. The flower is similar in structure to that of wheat. However, as in oats, the flowering glume and palea usually remain attached to the caryopsis. In both two-rowed and six-rowed barley the anthers and stigma mature at the same time.

Carruthers (1893) says that the pollen escapes from the anthers and is received on the moist stigma before the flower opens and while the ear is still within the sheath, the stigmas being dead when pushed beyond the glumes.

Bull (1915), in figuring barley heads at different stages of development, shows one half enclosed in the sheath and labeled "Head with but few flowers unfertilized" and another where the head is just out of the sheath labeled "Head emerging from the sheath with grain filling."

Both Delpino and Rimpau (Knuth, 1909) state that the middle row of flowers very seldom opens at all, but that the lateral ones open regularly. However, Rimpau declares that the anthers of six-rowed barley always dehisce while the glumes are completely closed.

Früwirth (1909) says that, in his experiments, emasculated heads of "four-rowed" barley gave good seed after blooming side by side with the same variety. He observed a succession of crosses where varieties of "four-rowed" barley were grown side by side, but none between "four-rowed" and six-rowed sorts or between varieties of six-rowed barley. He therefore concludes that there is a possibility of natural crossing in "four-rowed" barley but that selfing is usual and that there is practically no crossing in six-rowed varieties. As further evidence of the rareness of natural crossing he reports Rimpau as having cultivated on an average of forty varieties side by side and observed only eight plants in eight years which could be suspected of being crosses.

On the other hand Früwirth (1909) quotes Jamieson as mentioning the appearance of nine intermediate forms in the neighborhood of *H. dist. nutans* and *H. polystichum* and Tschermak as having observed spontaneous crossing in *H. dist. nutans*.

Delpino, Rimpau, and Kirchner (Knuth, 1909) agree that the flowers of the two middle rows seldom if ever open and the chances are greatly in favor of pollination between flowers of the same head if opening does take place.

RICE.

The inflorescence of rice (*Oryza sativa*) is a terminal panicle of complete allogamous flowers. The spikelets are one-flowered, the outer glumes are small, and the lemma is large, hard, and horny.

There are six stamens, the lodicules are strongly developed, and the stigma branches are red.

The blooming proceeds from the top of the panicle downward and from the free end of the panicle branch to its base. The flower opens before the anthers dehisce, but this occurs very soon afterward (6 to 12 minutes according to Früwirth, 1909). Hector (1913) says that in practically all normal cases dehiscence and pollination occur simultaneously with or sometimes before the opening of the flower, at a time when the stigmas and anthers are still within the shelter of the glumes. He also states that, just prior to opening, the anthers just touch the concave roof formed by the closed glumes and if at this stage the glumes are gently pulled apart, the anthers may be seen to dehisce and the pollen to fall in showers on the feathery stigmas within. The immediate causes of dehiscence probably are the pressure of the anther on the glume caused by the elongation of the filament, the sudden shock caused by the opening of the glumes, and the access of air and sunlight. Krauss (1907) also believes that dehiscence occurs normally before the anthers emerge from between the glumes and thinks that the stigma does not become receptive until the very moment the pollen is shed. On the other hand Knuth (1909) reports that Körnicke found that as the glumes open the closed anthers protrude laterally and bend outward, while the stigmas either project a short distance from the glumes or remain within them. The filaments grow longer, allowing the anthers to hang down, after which they dehisce some distance from the glumes by splitting from top to bottom.

Immediately after dehiscence the glumes spread further apart (30–35 degrees according to Früwirth). The filaments elongate, causing the anthers to protrude until their lower margin is above the top margin of the lemma, after which they bend outward and downward to a pendent position. By this time the anthers have lost practically all their pollen (Hector, 1913). The time occupied in the whole process is comparatively short. Hector says about 15 minutes elapse from the opening of the glumes to the time the anthers assume the pendent position. Früwirth (1909) observed the following interesting sequence: Flower began to open at 14 minutes after 10 o'clock; it was fully open at 14 minutes, 30 seconds, past 10; the anthers burst at 10:21; and the flower closed at 1:00 p. m. According to Früwirth, van der Stok found in Java that the extreme range of opening was from 6 a. m. to 3 p. m., but that most of it occurred between 10 and 12 o'clock. The flowers remain open from two to two and a half hours or, if pollination is delayed, four hours or even longer. The flowers opening early in the day remain open longer than those blooming toward midday.

Krauss (1907) believes that self-fertilization is the rule in rice since he grew more than 100 varieties in close proximity for from two to four generations without finding a single crossbred plant. Numerous individual plants of several varieties were protected from foreign pollen by double thickness fine gauze bags before the flowering stage and all fertilized perfectly except those experimented upon during periods of heavy rain. If the stigma fails to receive pollen from the anthers of the same floret, foreign pollen may fertilize it even after a considerable interval.

Früwirth (1909) says:

> While the mutual relation of anther and stigma welcomes self-pollination, cross-pollination is not prevented. Enclosure of single panicles in parchment bags resulted in a sparse setting of well-developed seeds. Forms blooming side by side are sexually influenced but seldom. Körnicke designated rice as cross-fertilized and in support of this view referred to the great number of intermediate forms which Hasskarl in Buitenzorg traced back to the frequency of spontaneous crossing.

From his own investigations Früwirth concludes that

> Self-pollination through tight enclosing is effective, giving well-developed though fewer seeds.

He also quotes van der Stok as holding that self-pollination is the usual process but that cross-pollination occurs occasionally.

Hector (1913) is of the same opinion, but holds that crossing is not precluded, since at times the stigmas may protrude from between the glumes and if the anthers have not dehisced before emerging, they hang down below the stigma so that selfing is impossible. Seed-setting is then conditioned by cross-pollination. This cross-pollination by the wind seldom, if ever, occurs at a distance greater than 1 to 2 feet. In lower Bengal under favorable conditions cross-fertilization may take place in rice to an extent which may be provisionally estimated at about 4 percent.

Ikeno (1914) figures and describes the successive stages in the opening of the rice flower and confirms results of previous investigators in that the anthers are open and the stigma showered with the pollen at the time of opening of the flower. He sowed alternate rows of blue-kerneled and red-kerneled rice. These types show xenia when crossed, with blue dominant. From 15,000 kernels from 190 panicles not a single case of xenia was found and he therefore concludes that natural crossing occurs very seldom.

Akemine (1914) for six years conducted some very careful experiments in Japan and summarizes his results as follows:

> Rice under unfavorable conditions sometimes forms cleistogamous flowers. The glumes normally open at an angle of thirty degrees. The opening is brought about by the swelling of the lodicule to three times its former thickness. The only change in the pistil is the lateral expansion of the style. Pollination takes place either immediately before or at the moment of the opening of the flower. Under favorable conditions, fertilization commences about twelve hours after the flowering and is complete after about one day. The opening of the glumes offers no absolute physiological advantage, since the fruits can form equally well when the flowers remain closed. Cross-fertilization often occurs in rice if the anthers do not assume their natural position either on account of incomplete development of unfavorable environmental conditions.

RYE.

The flowers of rye (*Secale cereale*) are perfect and quite similar in structure to those of wheat except that the anthers are much larger. The stigma and pollen mature at the same time. Kirchner, according to Knuth (1909), says that the flowers in favorable weather begin to open after sunrise and anthesis lasts till evening. The first flowers to open are situated at a height of two-thirds of the length of the spike and each flower remains open about fifteen minutes. In anthesis the anthers, according to Hildebrand, project between the still partly closed glumes until the bases of the anthers are protruded. They then tip over, spilling some of the pollen, but outside the flower. The glumes open more widely, the stigmas bend forward, and the anthers dehisce more fully. Being lower, however, they can not reach the stigma of the same flower.

From the foregoing it must be concluded that cross-pollination is the general process. Kirchner says if autogamy takes place, self-sterility is the result. In unfavorable weather the flowers do not open and no fertilization takes place. Rimpau and later von Liebenberg and Ulrich established the fact of the self-sterility of rye (Früwirth, 1909).

Fruwirth (1909) concludes from his experiments upon caged individual plants that, while the flowers are self-sterile, fertilization is possible between different flowers of the same head or between different flowers of different heads of the same plant. If such fertilization (i. e., between different flowers of the same plant) is forced, the setting is markedly smaller than under field conditions. However, the setting does not suffer if the plants meeting sexually are closely related to each other or even if longer continued inbreeding of a group of plants closely related to each other is undertaken.

The Experiment Station Record reports that Ulrich (1902) found rare cases of self-fertility, the number varying with the variety, but that self-sterility is normal.

Von Rümker (1909) found that by selecting for color of kernel he could obtain strains pure for various shades of green, yellow, and brown. In many cases the color was correlated with valuable qualities in the plant, such as stooling habit and yield. He concludes, therefore, that the color may be a practicable and useful aim for the rye breeder. He also notes that, like maize, rye shows xenia. At that time (1908) he expressed a doubt as to whether rye was cross-pollinated to such an extent as had been supposed, since his strains, although grown close together, retained and transmitted with a surprising degree of purity such characters as stooling, leaf form, leaf color, ear shape, and lodging.

Von Rümker and Leidner (1914) by inbreeding obtained pure lines which gave larger yields than the ordinary hybrid strains. This is in line with the theory of heterozygosis as enunciated by East and Hayes.

FLAX.

The flowers of flax (*Linum usitatissimum*) are borne in a terminal corymb. Each flower is complete and the five anthers mature simultaneously with the pistil. There are five nectaries located at the base of the filaments. The flowers are showy and are reported by Müller (1883) to enjoy a limited number of insect visits. The flowers open in the morning at about 6 or 7 o'clock, or in very cool weather even as late as 9 or 10 o'clock (Früwirth, 1909). Before the flowers have opened, the anthers are somewhat higher than the stigma but when fully open stand on a level with it. Within two hours after opening the pollen is all expelled (Früwirth, 1909), covering the anthers all around (Müller, 1883). The anthers and filaments wither and the petals close toward noon, falling off as evening approaches, though they may stay on until the next morning (Früwirth, 1909). Müller (1883) says that the distance between the pollen-bedaubed anthers and the stigma in an open flower prevents self-pollination, but if an insect inserts its proboscis outside the anthers, selfing is effected; if within the anther ring, crossing is likely. Failing insect visits, the wilting of the anther filaments and the closing of the flowers cause the stamens to bend inward until the stigma is touched, when self-pollination and self-fertilization result. Hildebrand has proved that selfing is efficient (Müller, 1883).

Früwirth (1909) says:

> Insect pollination is comparatively scarce. Self-pollination occurs by the closing of the flowers, but the possibility of cross-fertilization exists by remaining flowers close to them since insect visits at the beginning of blossoming of such a flower can cause such an occurrence. This possibility is very little made use of and distinctly different forms grown side by side in single rows keep themselves pure for years.

From his own investigations in enclosing the whole plant in parchment bags and also in fine netting he found that the number of fruits was not very different and often exactly the same when compared with the number of flowers on blooming plants. The capsules which were gotten from the enclosed plants were somewhat lighter and the number of seeds per capsule somewhat smaller than from unenclosed plants. The total weight of the capsules, the total weight of the seeds, and the number of seeds per plant were also usually smaller. Plants which were grown from seed from the enclosed plants proved through cultivation in the open field to be not less luxuriant than plants grown side by side with them under similar conditions which were grown from seed from unenclosed plants. Furthermore, after three generations of self-fertilization were forced through enclosing, the plants showed no debilitation. These data of Früwirth's seem to be good evidence for the statement that flax is normally self-pollinated.

Howard, Howard, and Rahman Kahn (1910) say:

> After three years of cultivation of single plants of the fiber-yielding linseed at Pusa we have no doubt that natural crossing takes place under Indian conditions.

Mr. Lee Alexander, nursery foreman at the Minnesota station, says that in growing flax in the nursery in centgeners 16 inches apart for twelve years he has never observed a plant which could be suspected of being a natural cross. This testing included numerous seed introductions which were propagated and grown as individual plant selections. Many of these introductions were mixtures of the yellow-seeded white-flowered flax with the brown-seeded blue-flowered type, both of which bred true for these characters.

Prof. J. H. Shepperd of the North Dakota station in a letter to the writer states that it is very difficult to get many of the characters of flax to breed true but that during many years' work with blue-flowered and white-flowered and with brown-seeded and white-seeded flax, he has never observed a plant which he could say was a natural cross. He is of the opinion, however, that crossing may take place between neighboring plants in the row.

SUMMARY.

The data here presented may be summarized as shown in Table 1.

TABLE 1.—*Summary of investigations on the fertilization of grain-crop plants.*

Crop.	Self-pollination.	Cross-pollination.	Factors causing deviation from normal.
Corn.	4 to 24 percent probable.	Normal.	Weather conditions, varietal differences in time of silking.
Wheat.	Normal.	Fraction of 1 percent.	Weather conditions, climate, varietal differences in divergence of glumes.
Oats.	do	Very seldom.	Structure of individual flower.
Barley.	do	Practically never, except in "4-rowed" barley.	
Rice.	do	Probably less than 5 percent.	Possibly weather conditions.
Rye.	Flowers self-sterile, though considerable crossing between flowers on the same plant may occur.	Normal.	Weather conditions.
Flax.	Normal.	Probably less than 1 percent.	

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CONTRIBUTIONS TO AGRONOMIC TERMINOLOGY—3.

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The present paper is a continuation of the second. That paper defined the terms concerning the vegetative portions of plants, while this contains the terms relating to the reproductive portions, namely, the flowers and fruits. A few new terms are proposed in this paper, as in the last. Such terms are indicated in the text as new, for the convenience of the reader.

Several letters of criticism and suggestion concerning the first paper have been received by the authors and are much appreciated. It is hoped that similar action will follow the appearance of the second and succeeding contributions.

Inflorescence.

inflorescence, *n.* 1. The flowering part of a plant. 2. The method of arrangement of the flowers.

ament, *n.* A spike with the bracts scale-like, as in the willow and birch.

catkin, *n.* An ament.

corymb, *n.* A flat-topped or convex flower cluster in which the pedicels are unequal and the outer flowers blossom earliest.

cyme, *n.* A determinate flower cluster, that is, one in which the central or terminal flowers bloom earliest.

ear, *n.* A large, dense, or heavy spike or spike-like inflorescence, as the ear of maize. Popularly applied also to the spike-like panicle of such cereals as wheat, barley, and rye.

fascicle, *n.* A compact bundle or cluster of flowers or leaves.

glomerule, *n.* A small, compact inflorescence; a cymose inflorescence condensed into a head, as in flowering dogwood.

head, *n.* A dense roundish cluster of sessile or nearly sessile flowers on a very short axis or receptacle, as in red clover, sunflower, etc.

involucre, *n.* A whorl or collection of bracts surrounding a flower cluster or a single flower. Conspicuous examples occur in the sunflower, thistle, and most other *Compositæ*.

involucel, *n.* A secondary involucre, as in the umbellets of plants of the parsley family (*Umbelliferæ*).

panicle, *n.* A loose, irregularly compound inflorescence with pediceled flowers, as in oats, rice, proso, Amber sorgo, bluegrass, etc.

peduncle, *n.* The primary stalk supporting either an inflorescence or a solitary flower. In grasses, the upper internode of the culm.

pulvinus, *n.* A cushion-like mass of tissue at the base of a petiole, petiolule, or branch of an inflorescence. A pulvinus is usually irritable and by variation in its turgidity promotes movement.

raceme, *n.* An elongated simple inflorescence with each flower pediceled, instead of sessile as in the spike.

rachilla, *n.* The axis of a spikelet.

rachis, *n.* 1. The axis of an inflorescence, especially of a simple inflorescence, as a spike or raceme. 2. The axis of a pinnately compound leaf, as in the pea, vetch, etc.

rhachilla, *n.* See rachilla.

rhachis, *n.* See rachis.

scape, *n.* A peduncle rising from the ground naked or with reduced leaves, as in the dandelion and the hyacinth.

spadix, *n.* A spike with a fleshy axis.

spathe, *n.* A large bract or pair of bracts inclosing an inflorescence.

spike, *n.* A simple inflorescence with the flowers sessile or nearly so on a more or less elongated common axis, or rachis. Familiar examples occur in crimson clover, plantain, and cowpea. The inflorescences of wheat, barley, rye, foxtail millet, and the ear of maize are in reality spike-like panicles, but the term spike is extended in common usage to include these.

spikelet, *n.* A small or secondary spike, especially in the inflorescence of grasses.

tassel, *n.* Popularly (in U. S.) the staminate inflorescence of maize (corn), which actually is an inflorescence composed of panicled spikes.

tassel, *v. i.* To produce tassels.

detassel, *v. t.* To remove the tassel, as in maize.

thyrse, *n.* A panicle that is cylindrical or pyramidal and rather compact, as in most sorghums (durra, feterita, kafir, milo, and many sorgos); also written *thyrsus.*

thyrsus, *n.* A thyrse.

umbel, *n.* An inflorescence in which the pedicels of a flower cluster spring from the same point, and the outer flowers bloom first.

umbellet, *n.* A small or secondary umbel.

Flowers.

anthesis, *n.* The period or act of flowering.

bloom, *n.* 1. A blossom. 2. A whitish or bluish-white, powdery, wax-like coating, as on a sorghum stem, a cabbage leaf, or a plum.

bloom, *v. i.* To blossom; to open, as a flower from a bud.

blossom, *n.* A flower; an individual unit of an inflorescence.

blossom, *v. i.* To burst into bloom.

bud, *n.* 1. An unexpanded flower. 2. The rudimentary stage of a stem or branch.

floret, *n.* A small flower, especially one of an inflorescence, as in grasses.

flower, *n.* 1. The part of a seed plant that bears ovules or anthers or both, with or without additional organs. 2. A modified shoot of a seed plant adapted for reproductive purposes, and consisting of a shortened axis bearing modified leaves, all or some of which are either stamens or carpels.

flower, *v. i.* To produce flowers; to bloom; to blossom.

square, *n.* An unopened flower-bud of cotton with its subtending involucral bracts.

Flower Stalks.

carpophore, *n.* The slender prolongation of the torus which supports the carpels, as in parsley and geranium; also called the *gynobase,* as in borage; when much elongated, to raise the pistil above the stamens, as in the caper family, it is called a *gynophore.*

disk, *n.* 1. The enlargement of a torus at the margin, or about the base of the pistil. 2. The portion of the head in *Compositæ* which contains only tubular flowers, as in the sunflower and artichoke.

gynobase, *n.* An enlargement or prolongation of the torus, supporting the ovary, as in borage; a carpophore.

gynophore, *n.* A much elongated carpophore.

hypanthium, *n.* A concave or cup-shaped torus, as in the apple

pedicel, *n.* The stalk on which an individual blossom is borne (compare peduncle).

receptacle, *n.* 1. The torus. 2. The portion of a head to which the flowers are attached.

torus, *n.* The more or less modified tip of a peduncle or pedicel of a flower, which bears the other floral organs.

Perianth (Calyx and Corolla).

perianth, *n.* The modified floral leaves, considered collectively, consisting of the sepals and, when present, the petals.

awn, *n.* A bristle-shaped appendage, especially when terminal.

banner, *n.* The upper, or posterior, usually broad petal of a papilionaceous flower, as in the pea family; the standard.

bract, *n.* A more or less modified leaf, usually reduced, subtending a flower, or belonging to an inflorescence, as in an involucre, or rarely below the inflorescence; a hypsophyll.

bracteole, *n.* A bractlet.

bractlet, *n.* A secondary bract, as one on the pedicel of a flower.

bristle, *n.* A stiff, sharp hair or any very slender body of similar appearance; a seta.

calyx, *n.* The sepals, or outer of the two series of floral leaves which form the perianth.

chaff, *n.* 1. A small, thin bract, becoming dry and papery. 2. The floral parts of cereals, separated from the grain in thrashing or winnowing.

corolla, *n.* The petals, or inner of the two series of floral leaves.

fall, *n.* The broad, usually drooping, perianth segments of an iris flower.

galea, *n.* A portion of a corolla or calyx when shaped like a hood or helmet.

glume, *n.* One of the (usually) two empty chaffy bracts at the base of the spikelet in the grasses.

hypsophyll, *n.* A bract.

keel, *n.* 1. The two anterior united petals of a papilionaceous flower. 2. A central (dorsal) ridge resembling the keel of a boat, as on the glumes of some grasses.

lemma, *n.* The lower of the two bracts inclosing each floret in the grasses; the flowering glume.

limb, *n.* 1. The expanded portion of a gamopetalous corolla above the throat. 2. The expanded portion of a petal, or sepal, or leaf.

lip, *n.* Either the upper or lower division of a bilabiate corolla or calyx.

lodicule, *n.* A minute scale at the base of the ovary opposite the palea in the grasses, usually two in number and probably representing the reduced perianth.

pale, *n.* A palea.

palea, *n.* The upper of the two bracts inclosing each floret in the grasses.

palet, *n.* A palea.

pappus, *n.* The modified calyx-limb in *Compositæ* and related families, consisting of teeth, bristles, awns, etc., surmounting the akene.

scale, *n.* A rather thin or expanded, reduced structure, either a leaf or a trichome.

seta, *n.* A bristle, or any slender appendage resembling a bristle.

sinus, *n.* The space between two lobes.

spur, *n.* A hollow sac-like or tubular extension of some part of a flower.

standard, *n.* The upper, or posterior, usually broad petal of a papilionaceous corolla; the banner.

throat, *n.* The portion of a gamophyllous calyx or corolla between the tube and the limb.

tube, *n.* The tubular portion of a gamophyllous calyx or corolla.

wing, *n.* 1. A lateral petal in a papilionaceous flower. 2. Any thin, broad expansion or appendage on an organ.

Pistils.

carpel, *n.* A simple pistil or one member of a compound pistil.

gynœcium, *n.* The group of pistils in a single flower.

ovary, *n.* The enlarged basal portion of a pistil which contains the ovules.

pistil, *n.* The seed-bearing organ of a flower, including ovary, style, and stigma.

stigma, *n.* The portion of a pistil, usually the tip, through which fecundation is effected by the pollen.

stipe, *n.* The base of an ovary when constricted to form a short stalk.

style, *n.* The slender upper part of a pistil, supporting the stigma.

stylopodium, *n.* The enlarged base of the style, especially in the *Umbelliferæ.*

Stamens.

andrœcium, *n.* The group of stamens in a single flower.

anther, *n.* The upper, usually enlarged portion of a stamen which contains the pollen.

connective, *n.* The sterile portion which connects the two sacs of an anther.

extine, *n.* The outer layer of the cell-wall of a pollen-grain.

filament, *n.* The stalk of an anther.

intine, *n.* The inner layer of the cell-wall of a pollen-grain.

pollen, *n.* The spores produced within an anther-sac.

pollen-grain, *n.* A grain of pollen.

pollen-tube, *n.* A delicate filament developed from the pollen-grain, which normally grows down through the stigma and style to the ovule.

stamen, *n.* One of the pollen-bearing organs of a flower, consisting usually of filament and anther.

staminode, *n.* A sterile stamen, or any structure corresponding to a stamen but without an anther.

MISCELLANEOUS.

callus, *n.* 1. Any small, hardened protuberance. 2. The hardened basal portion of the lemma in certain grasses.

gibbosity, *n.* An enlargement or protuberance swollen on one side.

gland, *n.* A secreting cell or group of cells.

lamella, *n.* 1. Any thin, plate-like expansion of an organ; a wing. 2. The layer of material between two cells of a tissue.

nectary, *n.* Any gland or organ which secretes sugar. A floral nectary is one borne on some part of a flower; an extra-floral nectary is one borne elsewhere on the plant.

sac, *n.* A pouch, as the cavity of an anther.

FRUITS AND SEEDS.

KINDS OF FRUITS.

fruit, *n.* The portion of a plant that contains the seeds, including any surrounding portion affected by the process of fertilization.

fructification, *n.* 1. The act of forming or producing fruit. 2. The fruit.

fruiting, *n.* The process of bearing fruit.

fruit, *v. i.* To bear fruit.

fructify, *v. i.* To produce or bear fruit.

achene, *n.* See akene.

akene, *n.* A small, dry, indurated, one-seeded and one-celled indehiscent fruit, as in the sunflower and other composites.

berry, *n.* 1. A fruit with fleshy or pulpy pericarp, in which the seeds are enclosed. 2. Any small, fleshy fruit irrespective of its structure.

boll, *n.* The dry subspherical or ovoid fruit of flax and cotton

boll, *v. i.* To form bolls.

capsule, *n.* A pod composed of more than one carpel.

caryocist, *n.* (C. V. P.) A fruit consisting of a caryopsis enclosed in a small, dry box composed of the united lemma and palea. as in millet.

caryopsis, *n.* A one-seeded dry fruit with the thin pericarp adherent to the seed, as in most grasses.

coleocist, *n.* (*new,* C. V. P.) A fruit consisting of a spikelet enclosed in a thickened, indurated case formed from the sheath, as in *Coix* (Job's tears).

cyathocist, *n.* (*new,* C. V. P.) A fruit consisting of a spikelet enclosed in a hollowed-out portion of the rachis, as in teosinte.

drupe, *n.* A fleshy or pulpy fruit with the endocarp hard or stony and containing usually a single seed; a stone fruit, as the plum.

drupelet, *n.* A diminutive drupe.

follicle, *n.* A pod of one carpel dehiscing by the ventral suture.

grain, *n.* 1. A caryopsis. 2. A collective term for the cereals. 3. Cereal seeds in bulk.

key, *n.* (or *key-fruit*). A samara.

legume, *n.* 1. Any leguminous plant. 2. The pod of a leguminous plant, consisting of one carpel and most commonly dehiscent by both sutures.

loment, *n.* A legume constricted between the seeds and breaking apart into one-seeded segments when ripe, as in the beggarweed.

nut, *n.* A hard, indehiscent, one-celled, one-seeded fruit, whether consisting of one or more carpels.

nutlet, *n.* A small nut.

pepo, *n.* The peculiar fruit of cucurbitaceous plants, containing numerous seeds embedded in a more or less fleshy pericarp and with the exocarp firm and tough, as in the pumpkin, etc.

pod, *n.* A dry, dehiscent fruit, as in the pea and bean.

pome, *n.* A fruit having several cartilaginous, papery, or bony carpels in an enlarged fleshy hypanthium, as in the apple and pear.

pyxis, *n.* A capsule that dehisces horizontally, the upper part opening like a lid, as in plantain and purslane.

samara, *n.* An indehiscent, winged fruit, as in the ash, elm, and maple; a key.

silicle, *n.* A short silique.

silique, *n.* The peculiar pod of cruciferous plants, consisting of two carpels, the valves of which fall away from the central partition.

strobile, *n.* An inflorescence or fruit with conspicuous imbricated bracts, as in the hop and the pine.

utricle, *n.* 1. A small bladdery, one-seeded fruit. 2. Any small bladder-like organ of a plant.

STRUCTURE OF FRUITS.

bran, *n.* The coats of a caryopsis, especially of wheat and wheat allies, consisting of pericarp and seed coats united.

columella, *n.* The axis of a capsule which persists after dehiscence.

cremocarp, *n.* A fruit consisting of two 1-seeded indehiscent carpels, which split apart at maturity, remaining pendent from the summit of a carpophore, as in the parsley family. Each half is called a hemicarp.

dehisce, *v. i.* To open in a regular manner, dependent on the structure of the organ, as the opening of the carpels of a fruit.

dehiscence, *n.* The act of dehiscing.

dissepiment, *n.* A septum in an ovary or fruit.

endocarp, *n.* The inner layer of the pericarp, when distinguishable.

epicarp, *n.* Exocarp.

exocarp, *n.* The outer layer of the pericarp, when distinguishable; epicarp.

hemicarp, *n.* One of the two carpels of a cremocarp. (See mericarp.)

induration, *n.* A hardening.

mericarp, *n.* 1. A hemicarp. 2. One of the carpels of a schizocarp.

mesocarp, *n.* The middle layer of the pericarp when there are three layers distinguishable.

operculum, *n.* A lid, particularly the dehiscent top of a pyxis, as in purslane.

pericarp, *n.* The matured wall of the ovary.

putamen, *n.* The hard part of a stone fruit immediately inclosing the seed.

pyrene, *n.* The seed-like nutlet of a small drupe or a drupelet.

replum, *n.* The persistent portion of some pods (siliques) after the valves fall away, as in mustard and cress.

sarcocarp, *n.* The fleshy part of a stone fruit.

schizocarp, *n.* A dry compound fruit which splits apart at maturity into several one-seeded, indehiscent carpels, as in alfilaria.

septum, *n.* A partition.

suture, *n.* The line of junction between contiguous parts, especially between the carpels of a pericarp or the edges of a carpel, usually the line of dehiscence.

valve, *n.* One of the pieces into which a dehiscent pod splits.

STRUCTURE OF SEEDS.

seed, *n.* The mature ovule, consisting of the kernel and its proper coats.

seed, *v. i.* To produce seed.

albumen, *n.* The endosperm.

aril, *n.* An appendage of certain seeds that develops from the funicle after fertilization.

arillode, *n.* An appendage of certain seeds that develops from the micropyle.

caruncle, *n.* Any excrescence or appendage about the hilum of a seed.

chalaza, *n.* The portion of an ovule or seed where the body and the integuments are united.

coat, *n.* A covering of whatever kind that functions protectively, as a seed coat; one layer of an integument.

cotyledon, *n.* A seed leaf; a leaf-like organ (one, two, or more) of an embryo or seedling, differing from the subsequent leaves.

embryo, *n.* The young plantlet in the seed or maturing ovule.

embryo-sac, *n.* The sac in the ovule which contains the egg-cell and usually some subsidiary cells; in further development the egg becomes the embryo and the embryo-sac becomes the endosperm.

endopleura, *n.* The inner seed coat.

endosperm, *n.* The substance that surrounds the embryo in many seeds, as the starchy part in a kernel of wheat or corn; the albumen. Morphologically, the endosperm is the remnant of the tissue produced by the embryo-sac and not consumed by the embryo before the seed became mature.

egg, *n.* The female reproductive cell either before or after fertilization, but before division.

endostome, *n.* The orifice through the inner coat of an ovule.

exostome, *n.* The orifice through the outer coat of an ovule.

foramen, *n.* An orifice of any kind.

funicle, *n.* The stalk of an ovule, or seed, by which it is attached to the placenta.

hilum, *n.* The scar on a seed, marking the point of attachment of the funicle.

integument, *n.* A mass of tissue, usually of several layers of cells, forming a protective covering; a coat or coats.

kernel, *n.* The matured body of an ovule; the seed minus its coats.

micropyle, *n.* The orifice of the ovule; the corresponding place on a seed.

nucellus, *n.* The body of an ovule.

ovule, *n.* The body which, after fecundation, becomes the seed.

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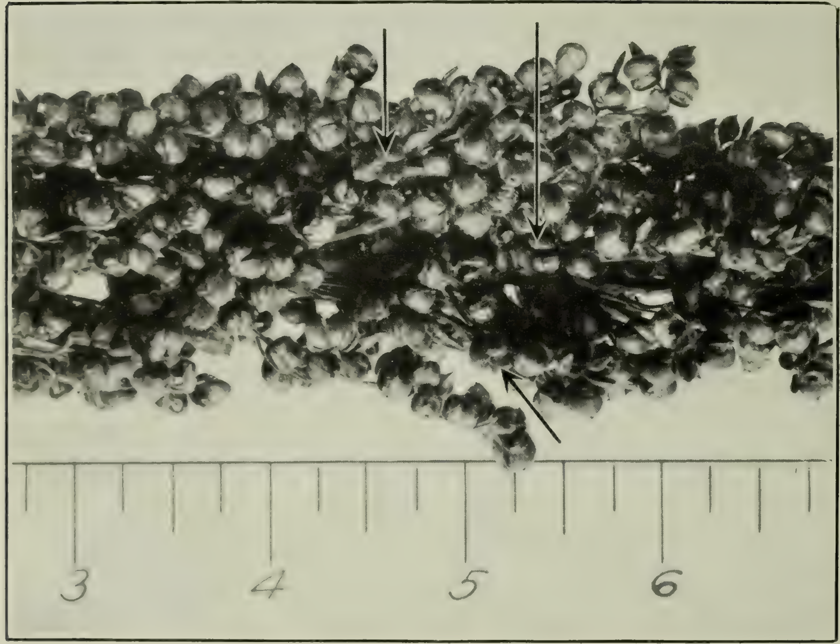

FIG. 1. A portion of the panicle of a milo-feterita hybrid showing the presence of three triple-seeded spikelets as indicated by the arrows. Natural size.

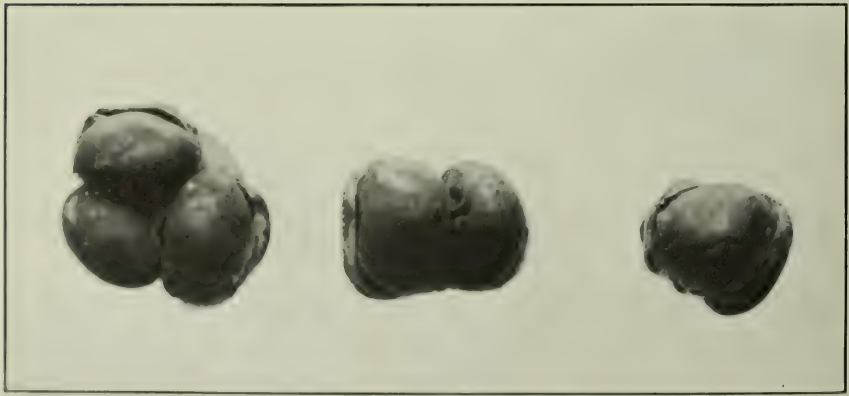

FIG. 2. Triple, twin, and single-seeded spikelets of milo-feterita hybrid, showing arrangement of the seeds in the glumes. Magnified 4 diameters.

perisperm, *n.* A layer of substance outside the endosperm in some seeds; morphologically it is the remnant of the nucellus not consumed by the embryo-sac in its development.

placenta, *n.* Any portion of the interior of an ovary from which the ovules arise.

primine, *n.* The outer integument of an ovule.

raphe, *n.* A portion of a funicle, adnate to the ovule or seed.

scutellum, *n.* An organ, often shield-shaped, forming part of the embryo in grasses, which does not emerge from the seed but functions to absorb the endosperm; morphologically it has been considered a cotyledon.

secundine, *n.* The inner integument of an ovule.

strophiole, *n.* An excrescence or appendage of certain seeds at the side of the hilum.

testa, *n.* The outer seed coat.

TRIPLE-SEEDED SPIKELETS IN SORGHUM.[1]

A. B. Cron,

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An abnormality in the inflorescence of sorghum which will perhaps be of interest to botanists and agronomists who are working with this crop was noted by the writer in the F_2 progeny of a dwarf-milo-feterita hybrid which was grown at Amarillo, Tex., in 1915. The unusual character was the presence of several triple-seeded spikelets and a larger number of twin-seeded spikelets in two of the panicles. Twin-seeded spikelets, although not common, are found in a number of durra varieties imported from India. No mention has been found, however, of twin-seeded spikelets in pure milo or feterita, and no such spikelets were found at any of the field stations where the Office of Forage-Crop Investigations is conducting experiments.

The above mentioned hybrid was made by H. N. Vinall in the greenhouses of the U. S. Department of Agriculture at Washington, D. C., during the winter of 1913–14. The F_1 and F_2 progeny were grown by the writer at Amarillo, Tex., in 1914 and 1915 respectively, and the seeds from the triple-seeded spikelets will be planted there

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[1] Received for publication February 15, 1916.

in 1916 to test their power of reproducing this character. Except for their being slightly more flattened the individual seeds in the triple-seeded spikelets are not different, either in form or size, from those in the single-seeded spikelets. Plate VIII, fig. 1, shows the occurrence of these triple-seeded spikelets in the panicle, and Plate VIII, fig. 2, the arrangement of the three seeds in the glumes.

Among a large number of durras in the varietal tests at Bard, Cal., in 1915, Mr. H. R. Reed, of the Office of Forage-Crop Investigations, found twenty-two white durras and one brown durra selected from a white strain that had twin seeds. One of these panicles of white durra, S. P. I. No. 14641, had one triple-seeded spikelet. These durra varieties were all imported from India. He also found an Orange sorgo, S. P. I. No. 20848, with numerous twin-seeded spikelets and one triple-seeded spikelet. One panicle of Denton sorgo, S. P. I. No. 2349, had several twin-seeded spikelets.

Carleton R. Ball,[2] in his "History and Distribution of Sorghums," page 11, says:

> As early as some of the ancient classics there is mention of a black millet which bore two seeds in each spikelet. So far as the writer is aware, there are no two-seeded varieties known either in the *Panicum miliaceum* or in *Setaria* (*Chætochloa*) *italica*. Several varieties of what may be called "twin-seed" sorghums are known in India.

On page 21 he says:

> One or two very large varieties are two-seeded, that is, they have two fertile flowers and produce two seeds in each spikelet instead of one as is normal for the sorghum.

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[2] Ball, Carleton R. History and Distribution of Sorghums. U. S. Dept. Agr., Bur. Plant Indus. Bul. no. 175. 1910.

THE PRESENT STATUS AND FUTURE DEVELOPMENT OF SOIL CLASSIFICATION.[1]

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The study of soils has not developed as a separate science like geology, chemistry, physics, or biology. The great body of soil knowledge which we now possess represents contributions made by men who were primarily geologists, physicists, chemists, or biologists rather than—we have no word to express the idea unless we coin the term—soilists.

Each of these men has looked at the soil from the viewpoint of his own particular science. To the geologist it has been the rock debris, constituting the land surface of the earth; to the physicist a natural body having certain physical characteristics and properties; to the chemist a substance composed of chemical elements combined in various and many ever-changing forms; and to the biologist a medium in which plants grow and many vital activities take place. To the "soilist" it is all of these and more; it is a geo-physico-chemico-bio-agricultural formation, a great independent, natural body in which the inorganic and organic kingdoms meet and which derives its peculiar characteristics and properties from this union.

As a result of this method of development several different systems of classification have been worked out in more or less detail. Of these the geological and physical have been most widely used although the chemical, climatic, and biological, as represented by vegetation, have also been given considerable attention.

The geological classification has been approached from at least three different angles: the kind of rock from which the soil has been derived; the agencies of formation; and the geological formation or age of the material. Of these the last might be considered as of least importance.

According to the first division soils are classified as granite soils, gneiss soils, limestone soils, shale soils, sandstone soils, etc. This

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[1] Read at the Berkeley meeting of the American Association for the Advancement of Science, August, 1915. Received for publication May 23, 1916.

classification really includes only the residual soils, or those which have been formed directly from the breaking down of the underlying rocks. Under the second division, which properly includes only transported soils since it is really the agencies of transportation of soil material upon which the classification is based, four subdivisions have been made,—glacial, æolian, alluvial, and colluvial. From the third viewpoint soils have been classified as Pre-Cambrian, Silurian, Carboniferous, Knox dolomite, Trenton limestone, Early and Late Wisconsin, etc. This classification was much more commonly used during the earlier development of soil survey work than at present.

Doubtless the obviousness of physical differences as well as their evident influence upon crops has caused the physical classification of soils to become very widely used, particularly among farmers and others especially interested in agriculture. This classification has been made principally from the standpoint of three different properties, although two, or even all three, have often been combined. These properties are texture, structure, and color. The last is really more significant as an indicator of chemical than physical differences.

According to differences in texture soils have been divided into sand, sandy loam, loam, silt loam, clay loam, clay, and some intermediate grades. This classification has been carried into more detail than any other. In fact some of the separations which are now being made have been carried to such a degree of fineness that there is very little, if any, appreciable agricultural difference between some of the classes. The making of four sandy loams—a coarse sandy loam, medium sandy loam, fine sandy loam, and very fine sandy loam —can hardly be justified on agricultural grounds. It is undoubtedly possible to detect differences in texture which have no appreciable effect upon the growth of plants.

The other two physical classifications, based on structure and color, although widely used have not been worked out as systematically as the textural. However, porous soils, impervious soils, loose soils, and black soils, brown soils, red soils, gray soils, etc., are very common terms among those actively engaged in handling the soil.

After the chemist discovered that plants obtain from the soil certain elements absolutely essential to their growth a great many soil samples were analyzed and attempts were made to classify soils according to the percentage of these elements which they contained. Perhaps the most important division which has been made from this standpoint is that relating to lime carbonate, or acid, neutral, and alkaline soils. However, we also have soils classed as high, medium, and low in nitrogen, phosphorus, potassium, or some other element.

Alkali soils should also be considered as a chemical division, representing those soils in which the concentration of soluble salts has been sufficiently high to injure plant growth.

The relation between the native vegetation and the character of the soil is often so evident that the classification of the latter according to the former would naturally appeal to any one interested in botany. Soils have, therefore, been classified as prairie and timber soils, pine barrens, oak and hickory uplands, chestnut soils, beech soils, maple soils, etc. The same principle is applied to cultivated crops when soils are spoken of as corn soils, wheat soils, potato soils, etc.

Soils have also been classified according to the character of climate under which they have been formed. Thus we have arid soils, semiarid soils, and humid soils. The Russian investigators have carried this classification into greater detail than any others and have divided the soils of the world into Laterite soils, Æolian dust soils, soils of the Dry or Desert Steppes, Chernozems, soils of the Wooded Steppes, Peat, Podzols, and soils of the Tundras.

These are the principal classifications which have been worked out from the different viewpoints. However, with the beginning of attempts at actually mapping the different soils, the inadequacy of any one of these systems in itself became apparent. Some of the reasons why this is true might be briefly given.

While all normal soils consist almost entirely of rock debris and their nature therefore depends very largely upon that of the rocks from which they have been derived, nevertheless, differences in the processes of weathering may result in very dissimilar soils from identically the same kind of rock. On the other hand long-continued weathering under similar climatic conditions may give rise to very similar soils from originally very different rocks. Then again, differences in rocks which may be very important from the rock standpoint, like that between granite, gneiss, and schist, may have a negligible influence upon the soil formed from them.

Whether the material has been laid down by water, wind, ice, or gravity undoubtedly determines to a considerable extent the character of the soil. However, just as the same chemical compound may be made by different methods so very similar soils may result from different methods of deposition. The character of the material has often been more largely determined by the source from which it came than by the agency of transportation. For example, glacial limestone drift is markedly different from that where the original rock was shale or sandstone. The alluvial wash from the "red beds" of Texas contrasts very markedly with that from the "black waxy" prairies.

The same geological formation usually gives rise to a variety of soils and not infrequently similar soils are formed from different formations. The separation of geological formations is based largely upon age, which may or may not have had an appreciable effect upon the character of the soil.

The geological classification is usually considered as being based upon origin, but it really includes origin only in so far as it relates to that of the soil material. The processes which have been acting upon the material since deposition, changing it from mere rock debris to actual cultivable soils, are left out. These processes have often produced more marked differences in the soils than have been caused by differences in material. The difference between the light-colored timber soils along the streams as contrasted with the dark-colored prairie soils is a good illustration. Variations in drainage conditions usually cause corresponding variations in the soil. Moderately poor drainage in the absence of lime carbonate will produce almost white soils, while a similar condition in the presence of lime will give rise to black soils.

Although there are few, if any, differences in soils of as great agricultural importance as that between a sand and a clay there are very great differences between soils of similar texture, which shows that this property alone is inadequate for a satisfactory classification. A similar statement might be made in regard to color, structure, and chemical composition, all of which are important because they represent actual differences in the character of the soil itself. However, in regard to chemical composition it may be added that only those chemical differences which can be detected in the field, like the presence or absence of lime carbonate, can well be considered in the classifying of soils. Chemical differences are often correlated with obvious physical differences, like color, or are evident from differences in plant growth. Chemistry can probably be of more value as a means of studying the differences which have been found than as a basis of classification.

Although natural vegetation is a valuable indicator of agricultural differences the classifying of soils upon this basis is going at the matter backwards; it is putting the effect before the cause. It is better to determine the differences in the soil which have caused these variations and base the classification upon these; otherwise the destruction of the vegetation will destroy the foundation of the system.

As these and other deficiencies made the use of any one of these systems entirely inadequate in itself, the next step was to unite all of them, in so far as practicable, in what might be termed a combination classification. This system has been developed principally by the Federal Bureau of Soils and is now the one most generally used. It is probably set forth in more detail in the report of the Committee on Soil Classification of the American Society of Agronomy[2] than anywhere else.

While this combination classification was undoubtedly a great improvement over the use of any of the single systems alone it nevertheless has its deficiencies and disadvantages. In the first place, it is quite complicated and therefore is very difficult to indicate in graphic form on a map. The showing of the detailed classification of the soils of a large area according to the complete system outlined in the report of the committee just referred to would undoubtedly be entirely impracticable. In the second place, the major divisions do not necessarily correspond to the most important differences in soils. Very much greater differences from an agricultural standpoint are found within the same large group than exist between many of the types belonging in different groups. The principal reason for this is that the factors upon which the subdivisions in some of the groups have been made may not have had any decided influence in determining the character of the soil.

The tendency at the present time is, therefore, to develop a system of classification based upon *actual differences in the character of the soil itself,* rather than upon a dissimilarity in the method of formation, the kind of rock from which it has been derived, or some other basis which may or may not have been an important factor in giving to the soil those properties and peculiarities that influence most its relation to crops.

For the working out of such a system in detail it is essential to have a knowledge not only of the peculiarities and differences in soils but also the relative importance of these in terms of crop production. While a great many valuable data have already been secured these must be more systematically arranged and further accurate ecological studies carried out before a satisfactory system based entirely upon soil differences can be made. However, this is the ideal towards which we should aim, although it may be impossible of attainment, at least for many years to come.

[2] JOUR. AMER. SOC. AGRON., v. 6, no. 6, pp. 284–288. 1914.

ALFALFA CROWN WART IN THE WESTERN UNITED STATES.[1]

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The alfalfa crown wart fungus was first observed in 1892 by von Lagerheim in Equador. He did not describe it, however, until 1898, when he published a description of it under the name of *Cladochytrium alfalfae*.[2] This name had been used with wrong spelling (*C. arfarfae*) in his and Potouillard's earlier work,[3] though in his article he confused it with *Urophlyctis leproides* (Trab.) Magn. In 1902 Magnus[4] transferred it to the genus *Urophlyctis* as *Urophlyctis alfalfae* (von Lagerh.) Magn., under which name it is now known. In a recent article Wilson[5] states that in life history studies of this fungus he finds "the presence of a plasmodium as the vegetative stage of the parasite and the entire absence of a mycelium at any stage," and suggests that possibly the organism should be removed from the genus *Urophlyctis*.

The alfalfa crown wart was first reported in the United States by McCallum[6] from Arizona. Since then it has been reported from California by Elizabeth H. Smith[7] and by R. E. and Elizabeth H. Smith,[8] from Oregon by O'Gara[9] and Jackson,[10] and from Utah by

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[1] Published by permission of the Secretary of Agriculture. Received for publication February 15, 1916.

[2] von Lagerheim, G. Mykologische Studien I, Beitrage zur Kenntnis der parasitischen Pilze, 1–3. Bihang Svenska Vetensk. Akad. Handl., Bd. 24, afd. III, no. 4, 1898. Abs. in Centbl. Bakt., II, 5, pp. 558–560.

[3] Potouillard, N., and von Lagerheim, G. Champignons d l'equateur. Bull. d. l'Herb. Boissier, 3: 62. 1895.

[4] Magnus, P. Ueber die in den knolliger Wurzelauswuchsen der Luzerne lebende Urophlyctis. Ber. Deut. Bot. Gesell., 20: 291–296. 1902.

[5] Wilson, O. T. The Crown Gall of Alfalfa. Science, n. s., 41: 797. May 28, 1915.

[6] McCallum, W. B. *In* Ariz. Agr. Expt. Sta. 20th Ann. Rpt., p. 583. 1909.

[7] Smith, Elizabeth H. A Note of *Urophlyctis alfalfae* in California. Science, n. s., 30: 211. 1909.

[8] Smith, R. E., and E. H. California Plant Diseases. Cal. Agr. Expt. Sta. Bul. 218, p. 1079. 1911.

[9] O'Gara, P. J. *Urophlyctis alfalfae*, a Fungus Disease of Alfalfa Occurring in Oregon. Science, n. s., 36: 486. 1912.

[10] Jackson, H. S. Oreg. Agr. Expt. Sta. First Bien. Crop Pest and Hort. Rpt., 1911–1912, p. 300. 1913.

O'Gara.[11] The reports of McCallum and E. H. and R. E. Smith are but little more than short statements of the presence of the fungus. O'Gara in his earlier article gives a more extended account in which he states that in the Rogue River Valley of Oregon in 1911 quite serious damage was being done to the alfalfa crop. Jackson describes the disease and reports considerable damage being done in Josephine and Jackson counties of Oregon. In the reports of Magnus[12] and von Lagerheim[13] they state that the disease is very destructive in Equador on moist land, but not so on the drier lands. Salmon[14] reports the disease as quite destructive in various places in Europe, but does not state under what conditions.

Whether or not this fungus is endemic in the western United States is not known. At the United States Plant Introduction Field Station, Chico, Cal., alfalfa plants grown from seed imported from Peru and sown in 1910 on land that had never grown alfalfa before had considerable crown wart in 1914. This may indicate that the spores of the fungus can be transferred with the seed and in this case had been brought from Peru, where the disease is known to exist. Plants of *Medicago falcata* grown at Highmore, S. Dak., where the disease is not known to exist, were received at Chico in the fall of 1913 in an apparently healthy condition. In 1914 and 1915 there were grown on land that had never grown alfalfa before. In 1915 a few of these plants had well-developed galls of the crown wart. This may indicate that the fungus is endemic in California but the fact that other diseased plants were on the station at the same time makes it possible that spores may have been transferred by means of implements used in cultivating.

For several years past the writer has been observing the alfalfa crown wart in the western United States with a view to determining the effects on alfalfa hay yields when the fungus is present in abundance. These observations have been made largely in the Sacramento Valley of California, where the fungus has been found quite widely distributed. In this region, alfalfa fields with practically every plant affected are not uncommon and good opportunity has been afforded for study.

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[11] O'Gara, P. J. Existence of Crown Gall of Alfalfa Caused by *Urophlyctis alfalfæ* in the Salt Lake Valley, Utah. Science, n. s., 40: 26. 1914.

[12] Loc. cit.

[13] Loc. cit.

[14] Salmon, E. S. *Urophlyctis alfalfæ,* a Fungous Disease of Lucerne in England. Gard. Chron., III, 39: 122. 1906. Jour. Southeast Agr. Col. Wye, Eng., 16: 296. 1907.

It is concluded from these observations that the crown wart decreases the yield of hay and shortens the life period of the plants, but nothing like the definite injury reported by O'Gara from the Rogue River Valley of Oregon, by Magnus and von Lagerheim from Equador, and by Salmon from Europe has been noted. Alfalfa fields that had the crown wart in abundance in 1914 produced good crops of hay in that year and in 1915. In one field sown in 1910 that has been under observation the past two years, practically every plant has galls. This field has produced apparently normal crops of hay, but more critical observation shows decreased vigor in the plants and a corresponding decrease in the yield.

Confirming the statements of O'Gara, the writer has found that the alfalfa crown wart occurs on light, sandy loams and even peat soils almost if not quite as abundantly as on heavier soils. However, it has been found in greater abundance on overflow lands than on higher lands and it may be that there is some relation between general moisture conditions and the occurrence of the fungus as indicated by Magnus's and von Lagerheim's statements of its more frequent occurrence on damp soils.

Under Sacramento Valley conditions, the fungus is in its active stage of growth the latter part of winter, spring, and early summer. By the middle of July practically all the galls are dry and disintegrating. Later in the season they disintegrate entirely and one finds little or no sign of the disease. In the spring, when the fungus is in active growth the crowns of the affected alfalfa plants are covered with a mass of tumorous outgrowths which enclose the spore masses. From the observations of the writer, this disease apparently is much more abundant and more widespread in the western United States than has generally been supposed. A thorough survey to determine its distribution and the damage done under various conditions needs to be undertaken. That sufficient attention has not been given to it is very evident and the large interests of the alfalfa crop certainly will justify the expenditure of time and money in such an undertaking. Whether or not it is possible and practical to control this fungus or reduce its injurious effects by the use of fungicides, crop rotation, or other means needs to be determined.

A PLAN FOR TESTING EFFICIENCIES OF FERTILIZERS.[1]

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Introduction.

No special plea is needed for the advisability of establishing standard plans for certain classes of fertilizer tests. The chief difference of opinion is concerning the model. When so many fertilizer tests are being conducted with the same object in view, such as tests of the relative efficiencies of different phosphates, it seems there should be some uniform plan, or at least, that there should be certain elements generally recognized as essential to every plan. In a previous paper attention was called to the gross inadequacy of the plans of many fertilizer tests.[2]

As a step towards more uniform methods, it is desired to suggest here one factor that should be considered essential in all tests of the relative efficiencies of fertilizers furnishing the same element, namely, that *several different quantities of the standard fertilizer should be applied.*

Usual Plan for Testing Efficiencies of Fertilizers.

It is generally considered sufficient in fertilizer tests to use only two quantities of the standard fertilizer, the yield from the larger application merely proving that the smaller application used in the comparison is not applied in excess of the crop's requirements. If the availabilities or efficiencies are to be calculated, as usually has been done hitherto, on the basis of the relative increases produced by certain quantities of the different fertilizers, the use of two quantities of the standard fertilizer is in some respects adequate. This method of calculating efficiencies is, however, open to objections. While it may give an accurate comparison, it is more likely to give a more or less inaccurate one. The method is based on an assumption concerning the law of minimum. It is assumed that up to the maximum of the crop's requirements equal increments of the fer-

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[1] Received for publication March 25, 1916.

[2] Gile, P. L., On the Plans of Fertilizer Experiments, Jour. Amer. Soc. Agron., v. 6, no. 1, pp. 36–41.

tilizer in minimum will produce equal increments in yield, that is, the curve of growth with increasing amounts of the fertilizer in minimum will be a straight line. As a matter of fact the curve of growth with increasing amounts of fertilizer may take a concave, convex, or irregular form under the variable conditions under which such tests are conducted. The more the actual curve deviates from the assumed straight line and the greater the variation in the yields produced by the different fertilizers, the greater may be the error if the efficiencies are calculated from the ratio of increased yields. Of course it is true that if the different fertilizers are applied in such quantities as to produce very nearly the same increases in yield, the comparison will be practically accurate by the latter method of calculation irrespective of the form of the "minimum" curve; but to secure such a result virtually presupposes a knowledge of how the experiment is going to come out before it is executed.

Proposed Plan for Testing Efficiencies of Fertilizers.

A more accurate method of comparison is on the basis of the relative amounts of the different fertilizers required to produce the same yields. This proposed method of comparison necessitates the application of several quantities of the standard fertilizer, so a curve may be constructed showing the increments in yield produced by increments of the standard fertilizer. By interpolating in the curve, the quantity of standard fertilizer can be found which would have been required to produce the same yield as that actually produced by any of the other fertilizers. The ratio of the quantities giving the same yields is the relative efficiency of the two fertilizers. This method of calculating efficiencies of different fertilizers furnishing the same element is independent of any assumptions concerning the law of minimum. It is valid whatever form the curve of yield with increasing fertilizer may take. The method is essentially the same as a colorimetric method in chemical analysis.

Just the number of different quantities of standard fertilizer that should be applied in tests of the efficiencies of different fertilizers furnishing the same element depends somewhat on the degree of accuracy sought and somewhat on the previous knowledge of the soil. Three quantities would afford a fairly close comparison if all were below the maximum; four quantities doubtless give as great accuracy, as far as the form of the curve influences the results, as can be obtained in any ordinary experiment. If the soil's requirements are not definitely known it is well to apply one extra quantity in case one of the quantities should be in excess of the maximum amount or so close to it as to be valueless in the comparison. Hence three to five quantities of the standard fertilizer should be used, depending on the conditions of the test.

Whether the model plan, besides including several quantities of the standard fertilizer, should include more than one quantity of the other fertilizers to be compared, is somewhat of an open question. For all ordinary tests of the efficiencies of different fertilizers furnishing the same element one quantity of all fertilizers except the standard is probably sufficient. If very detailed information is sought concerning the relative efficiencies it might be well to apply two quantities of the other fertilizers, as under certain conditions their relative efficiency might vary with the quantities applied, due to different secondary effects (of basicity, etc.) of the two fertilizers.

In pot experiments at this station the relative efficiencies of acid phosphate, floats, and three phosphatic guanos did not vary appreciably with the quantity of the fertilizers applied, as may be seen from Table I. In these experiments the standard series of pots with acid phosphate received 0.3, 0.6, 0.9, 1.35 and 2.03 grams of P_2O_5.

TABLE I.—*Relative efficiency of various phosphates as influenced by the quantity applied, in comparison with the P_2O_5 of acid phosphate taken as 100.*

Fertilizer.	Grams P_2O_5 applied per pot.	Efficiency.	Grams P_2O_5 applied per pot.	Efficiency.	Grams P_2O_5 applied per pot.	Efficiency.	Grams P_2O_5 applied per pot.	Efficiency.
Guano No. 508	3.6	2	14.4	1				
Guano No. 509	3.6	2	7.2	3	14.4	3	28.80	2
Floats	6.0	7	18.0	4				
Guano No. 734	1.2	39	1.8	36	2.7	39	4.05	45

The plans or accuracy of most fertilizer tests are such that there are fewer than one would expect which furnish information on this point. In tests of different phosphates by Wagner,[3] where two quantities of each were applied, practically the same relative efficiencies (calculated by the usual method) resulted from the smaller as from the larger application. In a comparison of horn meal with nitrate of soda, also by Wagner,[4] where eight different quantities of each were applied the relative efficiencies for increasing quantities applied were respectively; (92?), 68, 59, 52, 60, 61, 59 and 57 percent, as calculated by the proposed method. Most of Wagner's tests of the efficiencies of different nitrogenous fertilizers gave similar results.[5]

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[3] Wagner, Paul. Der Fall Soxhlet, p. 91. Darmstadt, 1911.

[4] Data from Mitscherlich, E. A. Landw. Vers-stat., bd. 75, nos. 3–4, p. 249.

[5] Wagner, Paul. Die Stickstoffdungung der Landwirtschaflichen Kulturpflanzen. Berlin, 1892.

Advantages of the Proposed Plan.

The use of several quantities of the standard fertilizer in comparative tests, besides affording a more accurate method of calculating results, has several advantages over the old method of using only two quantities. These advantages are apparent from a consideration of some curves taken from actual experiments on the efficiencies of different nitrogenous and phosphatic fertilizers,[6] as shown in figure 8.

From the form of the curve we can tell when a calculation of relative efficiencies is allowable and can get some idea of the accuracy of the comparison. Taking Curve III (fig. 8), which represents the increases in growth produced by increasing amounts of acid phosphate in an experiment on the efficiencies of different phosphates, the regularity of the curve up to point 4 and the sudden flattening between points 4 and 5 show that the maximum crop with acid phosphate would probably have been produced by some quantity slightly greater than *d* and less than *e*. Therefore if one of the other phosphates had produced a yield greater than that represented by point 4, it would only be allowable to assert that the relative efficiency was

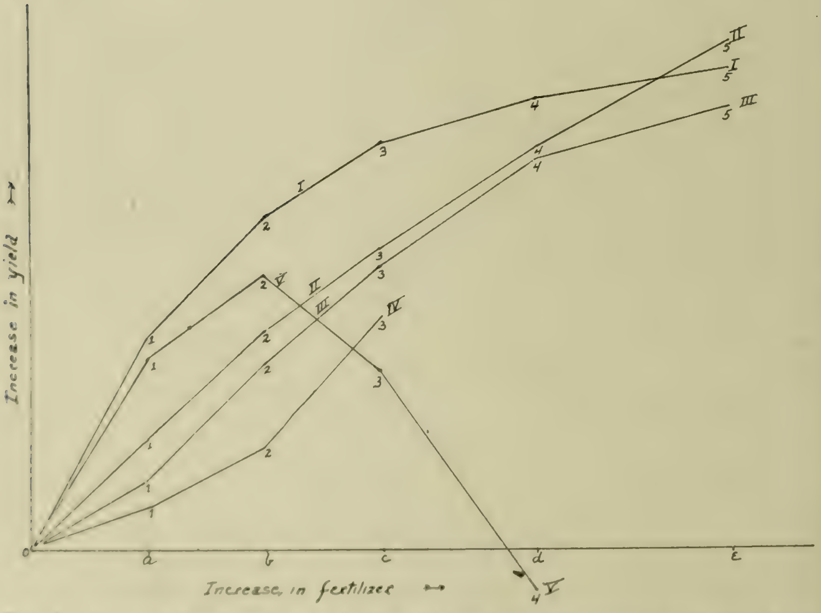

Fig. 8. Curves showing the efficiencies of various nitrogenous and phosphatic fertilizers at the Porto Rico station.

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[6] Unpublished results secured at the Porto Rico station.

at least a certain figure. In the experiment from which Curve I (fig. 8) was taken, if one of the other phosphates had produced a yield between those represented by points 4 and 5, a figure could be given for the efficiency, the regular form of the curve showing that the maximum crop with acid phosphate would have been produced by *e* or some greater quantity. This figure would be subject to some doubt, however, unless the experiment were extremely accurate, as large increases of the fertilizer between points *d* and *e* would have produced relatively very small increases in yield.

In the experiment from which Curve II was plotted it is evident that if a phosphate gave a yield between points 4 and 5 its efficiency could be calculated with considerable accuracy, the optimum amount of acid phosphate in this case being plainly *e* or greater, and quantities of acid phosphate between points *d* and *e* giving marked increases in yield. Similar conclusions can be drawn concerning the experiment which gave Curve IV, although the form of the curve is quite different from II. Here it appears that quantity *c* probably does not represent the optimum amount of fertilizer, and it is evident that efficiencies calculated from quantities of fertilizer giving yields between points 2 and 3 are more accurate than those calculated from quantities giving less yields, the curve being sharper between points 2 and 3.

The proposed method of calculating efficiencies involves the idea of always comparing yields of nearly the same magnitude, that is, for every yield from different fertilizers used in the test there is an approximately equal yield from the standard fertilizer, a point actually determined on the curve. This characteristic of the proposed method renders it unaffected by certain conditions that may be slight sources of error in the usual method of comparing efficiencies. For instance, yields of varying vigor of growth generally differ in several respects, such as in percentage of dry matter and mineral matter, and in degree of maturity.[7]

If the percentage of dry matter is less in the larger yields, or greater, as it may be when the larger yields are attended by more complete maturity, it would seem important to determine both the green and dry weights of the crops.[8] There is considerable difficulty and inconvenience in doing this in field experiments, the securing of a true sample of a plot being a problem in itself. If the proposed method is used, however, there is often no necessity of determining both green and dry weights, inasmuch as we are practically comparing equal yields, yields that should therefore have the same maturity and percentage of dry matter. As a matter of fact, in a considerable number of pot experiments where this method was used, there was practically no difference between efficiencies calculated from green or dry weights. In a number of pot experiments with millet where the plants were grown to maturity but cut before the leaves commenced to wither, the efficiencies of 82 phosphatic guanos were determined from both green and dry weights. In 83 percent of the cases the difference between the efficiencies as determined by green and dry weights was 2 or less, and in 94 percent of the cases the difference was 4 or less. In a number of other experiments corn, grown to about half maturity, was used in testing the efficiencies of 55 phosphatic guanos. In 80 percent of the cases the difference between efficiencies calculated from green and dry weights was 2 or less, and in 91 percent of the cases the difference was 4 or less. Of course under certain circumstances a determination of the dry weight is necessary whatever plan is used for the test.

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[7] The effect of an abundance of phosphates in hastening maturity and of an abundance of nitrogen in delaying maturity frequently have been noted.

[8] In one experiment where corn was grown for sixty days the percentage of dry matter in the green crop ranged from 11.4 percent for the no phosphate plants to 16.7 percent for those abundantly supplied with phosphates. This considerable difference was doubtless due to the greater maturity of the plants receiving most phosphate.

Similar reasoning applies to the determination of nitrogen, phosphoric acid, and potash in the crop.[9] With increasing fertilization the percentages of these elements often increase quite markedly in the crop, phosphoric acid to a less extent than nitrogen and potash. If the proposed method of determining efficiencies is used there should be no error due to not analyzing the crop, as approximately equal yields are compared. In most tests it makes no practical difference whether the low efficiency of a form of nitrogen, for instance, is due to a slow availability, or to the crop requiring a larger amount of nitrogen when supplied in that particular form.[10]

Because of the peculiar conditions affecting vegetative experiments in pots it is probably more important in such experiments than in field tests to use the proposed method of determining efficiencies. In nearly all vegetative experiments in pots the size of the pot in relation to the size and number of plants grown affects the yield somewhat. Small plants are at a relative advantage over big ones in that the ratio of soil to root volume is greater for small yields than for large ones.

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[9] The determination of these elements in the crop is often subject to doubt, as the percentage of the elements in the plant is affected by so many other conditions beside the fertilization. The stage of maturity, the removal of soluble matter by the leaching of rain or dew, or, as some hold, the return of mineral matter to the soil through the roots, may produce important changes in the mineral content of the plant.

[10] According to Russell (Soil Conditions and Plant Growth, p. 31. London, 1915), plants fertilized with sulfate of ammonia contain higher percentages of nitrogen than those fertilized with nitrate of soda. This ought not to be laid down as a general rule, however, as data are by no means uniform on this point

The water supplied may favor slightly the larger yields, especially where distilled water can not be used. A pot of a low yield of 30 grams of dry matter would probably receive about 13 liters of water during an experiment, while a pot of high yield, say 100 grams of dry matter, would receive 40 liters. If the water contained any favorable mineral elements the pot receiving the 27 liters more water would be at an advantage. It is thus evident that it is advisable to use a method where comparisons are made between yields that have been exposed to the same conditions.

Conditions Affecting the Form of the Minimum Curve.

As a minimum curve, whether used directly or assumed, plays an important part in tests of the efficiencies of different fertilizers it is of interest to consider some factors affecting its form. According to Mitscherlich the curve, for sand cultures at least, should be similar to I (fig. 8) and can be mathematically expressed by a logarithmic formula.[11] This is a common form of the curve and, if we admit it is the ideal form, it may nevertheless be greatly modified by various circumstances.

In experiments with phosphates the curve can be modified by the soil acting on the phosphate so as to render a portion of it unavailable. If a certain amount is fixed absolutely this would produce a jog in the curve or tend to flatten it. If a proportion of the whole is fixed, the proportion diminishing with the quantity of phosphate added, the actual curve would approach a straight line. The slight depression at point 1 on Curve III (fig. 8) may be due to some such action; it is evidently not accidental as it occurred at the same place in 9 experiments out of 13 with different lots of the same kind of soil. Some secondary effects of fertilizers should cause the curve to assume a form similar to I, particularly in pot cultures. In certain soils the acidity of acid phosphate may be more or less injurious, so that as the supply of phosphorus is increased the injurious acidity is also increased. As the acidity of the acid phosphate would evidently exert more influence the heavier the application, the smaller amounts of acid phosphate should be relatively more effective and the curve should approach the form I. In several pot experiments a depressing effect of the heavier applications of acid phosphate was observed, the young plants in the highest phosphate pots being inferior to plants with a smaller supply of acid phosphate. Later, the phosphate supply being so much the dominating factor in the growth, the plants with the greatest amount of acid phosphate gave the greatest yield. The yield, however, should have been still larger, had there been no depressing action during the early growth of the plant.

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[11] Mitscherlich, E. A. Bodenkunde. Berlin, 1913. Even if Mitscherlich's formula represents the ideal form of the minimum curve, it can hardly find practical use in calculating efficiencies, inasmuch as the object of nearly all such tests is to find, not an ideal value or availability of a fertilizer, but its efficiency under certain unideal conditions.

In two pot experiments secondary effects of dried blood produced marked alterations in the curve. During the early growth of corn and millet the larger applications of dried blood depressed the growth considerably below that of the no-nitrogen plants. For the young plants the curve of growth with increasing amounts of dried blood would have been similar to Curve V (fig. 8). After a time the injurious effect of the heavy applications of blood seemed to disappear and the growth of the plants was greatly promoted, the curve of growth given by the more mature plants being similar to I. The markedly injurious effect of the heavy applications of dried blood at first was probably due to some injurious compounds formed in the primary decomposition of the material, compounds which were later further decomposed.

In the use of phosphates we might have one factor tending to make the curve of growth take a concave form and at the same time another factor influencing it to assume a convex form. We might have a case where the soil rendered unavailable a certain portion of the phosphate applied, and at the same time have an adverse influence from the increasing acidity of the higher applications of acid phosphate. Under such conditions it is difficult to predict what form the minimum curve might take.

Attention has already been called to another condition that tends to give the minimum curve the form I, namely, that the percentage of a fertilizing element in a plant often increases with increasing amounts of fertilizer before the fertilizer applied is in excess.[12]

In the field tests adverse weather or other conditions may tend to produce a concave or sometimes a convex curve. Early vigor of a plant induced by abundant fertilization might enable it to withstand adverse conditions that would seriously retard less vigorous plants. Thus the larger applications of fertilizer might be relatively more advantageous than small ones. Probably some such conditions produced Curve IV, which was obtained from a field experiment with sugar cane.

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[12] Gile, P. L. On the Plans of Fertilizer Experiments. JOUR. AMER. SOC. AGRON., v. 6, no. 1, pp. 36–41. 1914.

SUMMARY.

It is proposed that tests of the efficiencies of different fertilizers furnishing the same element shall include applications of three to five different quantities of the standard fertilizer, and that from the data of the tests so planned, the efficiencies be calculated on the basis of the relative quantities of the different fertilizers required to produce the same increased yields.

It is pointed out that the usual method of conducting such tests and the usual method of calculating efficiencies may be subject to some error, as they are based on an assumption concerning the law of minimum, namely, that the curve of increased growth with increasing amounts of the fertilizer in minimum will be a straight line. This assumption is sometimes false, as the curve may take a variety of forms. Attention is called to some conditions affecting the form of the curve.

Some of the advantages of the proposed method are mentioned. Being based on no assumption concerning the law of minimum, an accurate comparison is possible irrespective of how the yield increases with increasing amounts of the fertilizer in minimum. The form of the curve, plotted from the increased yields produced by increasing amounts of the standard fertilizer, shows when a calculation of relative efficiencies is allowable and gives some idea of the accuracy of the comparison. As the proposed method involves the idea of always comparing yields of approximately equal magnitudes, an analysis of the crop and determination of dry matter are not so important as in the old method. This principle of the proposed method is of particular value for vegetative tests in pots where large and small yields are subject to somewhat different conditions in respect to ratio between soil and root volume and total amount of mineral matter supplied in the water.

THE HISTORY OF KENTUCKY BLUEGRASS AND WHITE CLOVER IN THE UNITED STATES.[1]

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Few of our common forage crops are indigenous to America. The vegetation which supplied the needs of the native wild animals was not so productive as the cultivated crops grown in Europe. The Indians in the present boundaries of the United States kept no herbivorous domestic animals and had no use for forage. The forage crops which they raised were used to produce food for man. The crops grown by the Indians before the discovery and settlement of America, which are now used more or less for forage, are: Indian corn (*Zea mays*), pumpkins (*Cucurbita pepo*), cassava (*Manihot utilissima*), beans (*Phaseolus* sp.), and sweet potatoes (*Ipomœa batatas*). None of these was native to the Old World. The first English settlers in America brought seeds of European forage plants with them. These were sown and many of them flourished exceedingly well.

There has been considerable difference in opinion among writers in regard to whether Kentucky bluegrass and white clover are natives of America or not. It is well known that they are natives of the Old World. Most biologists insist that they are not natives of America, while many popular writers refer to them as being indigenous to all limestone soils. The information presented here is taken from the writings of the early explorers and settlers and the earliest available books on American agriculture. While the data collected do not definitely decide the matter, they do throw considerable light on the subject.

The reason assigned by biologists for considering that these plants are not native to America is based on the fact that but few plants and animals are indigenous to both Eurasia and America, except those of arctic or subarctic regions. There were two lines of entry of plants and animals to North America from the Old World, one by the way of Greenland to Labrador from Europe, the other through Alaska from Asia. If the range of the plant or animal immigrant is not continuous through either of these routes, it is considered strong evi-

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[1] Received for publication March 29, 1916.

dence that the species was introduced after the discovery of America. Bluegrass and white clover grow as far north as Canada, but they have never been found native either in Labrador or Alaska. This evidence of their not being native to America is difficult to refute. There are apparently a few minor exceptions to the general rule stated above, but it holds true in the great majority of cases.

COMMON NAMES OF KENTUCKY BLUEGRASS.

One of the difficulties in deciding on the early history of Kentucky Bluegrass (*Poa pratensis*) comes from the multiplicity of common names which have been applied to this plant. Not less than twenty-seven different common names, most of them applied locally by farmers, have been used to designate it. They are bluegrass, browntop, common meadow-grass, common spear-grass, English blue-grass, goose-grass, green-grass, green meadow-grass, green poa, greensward-grass, Indian bluegrass, June-grass, Kentucky bluegrass, lawn-grass, meadow-grass, prairie June-grass, red-top, Rhode Island grass, smooth-stalked meadow-grass, spear-grass, spire-grass, summer-grass, white-top, wire-grass, and yard-grass. Most of these are no longer in use and some, notably red-top and goose-grass, are now commonly applied to other plants. Bluegrass, Kentucky bluegrass, and June-grass are now used almost exclusively for *Poa pratensis*.

The two plants, Kentucky bluegrass and white clover, are taken together because they are so often found in association in nature and because both were so frequently mentioned by the same writers. The evidence indicates that one is as likely to be native to America as the other. While it is not always clear that the term bluegrass or some of the other common names means *Poa pratensis*, white clover appears almost always to have meant nothing but *Trifolium repens*.

THE NATURAL VEGETATION OF AMERICA.

A knowledge of the character of this continent at the time of its settlement by Europeans is essential in understanding many of the references here given. This is easily obtained from the journals and letters sent back to the Old World by the first American explorers. Many of these writings were afterward published. Along the Atlantic Coast was one vast forest, with the exception of the swamps, ponds, and rivers, and the clearings made by the Indians. The forests, usually filled with vines, briars, and weeds, were so thick that travel through them was difficult. Near the Indian settlements, however, there was much cleared land and open woods. The

Indians gathered all the finer undergrowth over a large radius about their dwellings for fuel, and they often killed the trees on quite extensive areas to provide space for growing their corn, beans, and tobacco crops. When fuel became too scarce or too difficult to obtain, they often moved to another locality. In many cases they burned large areas annually to facilitate finding and stalking their game.

References Relating to the Atlantic Coast.

The earliest English reference found that has in any way a bearing on the question of whether or not these plants are native to America is that of Capt. John Smith[2] in his description of Virginia published in 1612. He wrote:

> Virginia doth afford many excellent vegitables and living creatures, yet grasses there is little or none but what groweth in lowe Marishes for all the country is overgrowne with trees whose droppings continually turneth their grasse to weedes by reason of the rankness of the ground.

In his General History of Virginia, published in 1629, he wrote:

> James Towne is yet their chiefe seat most of the wood destroyed, little corne there planted, but all converted into pasture and gardens; wherein doth grow all manner of herbs and roots we have in England in abundance and as good grasse as can be. . . . Here in winter they have hay for their Cattel; but in other places they browze upon wood and the great huskes of their corne with some corne in them doth keepe them well.

Again in writing in 1630 about New England, he stated:

> There is grasse plenty though very long and thick stalked . . . you may have harsh sheare-grass enough to make hay of, till you can cleare ground to make pasture; which will beare as good grasse as can grow anywhere as now it doth in Virginia.

Smith apparently did not recognize any native plants that might be valuable for pastures or he probably would have mentioned them.

The earliest direct American reference found is that of William Penn[3] in 1685. He mentioned sowing English grass-seed in his courtyard as an experiment. He says:

> It grew very thick but I ordered it to be fed (grazed) being in the nature of a grass plot on purpose to see if the roots lay firm and though it had been

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[2] Smith, Capt. John. Works, 1608-1631; edited by Edward Arber, pp. 56, 887, 951. Birmingham, 1884.

[3] Penn, William. A Further Account of the Province of Pennsylvania, p. 297

> mere sand cast out of the cellar but a year before the seed took much root and held the earth so fast and fastened itself so well in the earth that it held and fed like old English ground.

In the same year, 1685, Thomas Budd[4] advised farmers to sow English grass-seed on drained low grounds. He stated that, if English hay-seed was sprinkled on the land without plowing and sheep fed on it, the grass would soon cover the ground. While English hay usually meant a mixture of timothy, bluegrass, and probably red clover, the use of English grass appears to have been more restricted to *Poa pratensis*. The New England Almanack for 1720 makes this statement for June: "Cut your English grass." It was customary in those early times to use the term "Indian" in contradistinction from "English;" as, "Indian harvest" as against "English harvest," and "Indian corn" as against "English corn." If *Poa pratensis* had been native to New England, probably it would not have been called "English grass."

Jared Eliot[5] in his essays written 1747–51, in Connecticut, speaks of "English spear grass" and "spire grass commonly called English." Binns,[6] Butler,[7] Deane,[8] Jefferson,[9] and Peters,[10] all eighteenth century writers, mention one or the other or both of these plants. The earliest reference giving a botanical name is that of Kalm,[11] who mentions finding in 1750 "Poa angustifolia" in Canada. As *Poa angustifolia* closely resembles *Poa pratensis* it does not appear to be important which was meant. Deane is the first to give the name *Poa pratensis*. He wrote in 1790 of "Redtop or what is called English grass," and again in 1797 of the "Redtop grass *Poa trivialis et pratensis*." Kalm also wrote in regard to Pennsylvania:

> This country does not afford any green pastures like the Swedish ones; the woods are the places where the cattle must collect their food. . . . The trees

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[4] Budd, Thomas. Good Order Established in Pennsylvania and New Jersey in America.

[5] Eliot, Jared. Essays on New England Husbandry, p. 114 of 1st ed. (1790), and p. 137 of 2d ed. (1797).

[6] Binns, John A. A Treatise on Practical Farming. Frederick, Md., 1803.

[7] Butler, Frederick. The Farmers' Manual, p. 27. Weathersfield, Conn., 1821.

[8] Deane, Samuel. The New England Farmer or Georgical Dictionary. Worcester, Mass., 1790.

[9] Jefferson, Thomas. Notes on Virginia, 1st ed., 1782, p. 69.

[10] Peters, Richard. Agricultural Enquiries on Plaister of Paris. Philadelphia, 1797.

[11] Kalm, Per. *In* John Pinkerton's General Collection of the Best and Most Interesting Voyages and Travels in Various Parts of America, v. 3. London, 1819.

> stand far asunder, but the ground between them is not covered with green sods; for there are but few kinds of grasses in the wood and they stand single and scattered.

This quotation has considerable weight when we consider the fact that Kalm was a competent botanist and was familiar with the poas and white clover.

The first reference to the natural spread of these plants was in 1747. Neal wrote in his History of New England: "The soil of this country is very rich and naturally produces English grass, of which there is a great plenty." Benjamin Franklin,[12] writing in 1749 to Jared Eliot, says:

> The grass which comes in first after ditching is spear-grass and white clover. . . . I have sown two bushels of the sweeping of hay lofts (where the best hay was used) well riddled per acre, supposing that the spear-grass and white clover seed would be more equally scattered when the other shall fail.

This characteristic was frequently mentioned by later writers. "Green grass and white clover appear spontaneously when the land is cleared" was a favorite method of describing the northeastern part of this country.

The question whether Kentucky bluegrass and white clover are native to America or not does not appear to have been considered for at least one hundred years after definite mention was made of their being grown here. Jefferson in his "Notes on Virginia," 1782, gives a partial list of native plants but does not include in that list either *Poa pratensis* or *Trifolium repens*. He states in another paragraph, however:

> Our grasses are lucern, St. foin, burnet, timothy, ray and orchard grass; red, white, and yellow clover; greensward, blue grass and crab grass.

Strickland,[13] who traveled in the United States in 1794, stated:

> I am told it (white clover) is never met with far back in the woods, but immediately on their being cleared away either by fire or otherwise it takes possession of the ground, which should prove that it was natural to it; that the seed lies there but cannot vegetate till the ground is cleared; but again I have been told that by some tribes of Indians it is called "White man's foot grass" from an "idea that wherever he has trodden it grows"; which should prove at least that it had not been known in the country longer than the white man.

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[12] Smyth, Albert Henry. Life and Writings of Benjamin Franklin, 2: 383. 1907.

[13] Strickland, William. Observations on the Agriculture of the United States. *In* Rept. British Bd. Agr., 1801.

James Mease[14] of Philadelphia did not agree with this. He wrote in 1804:

> White clover whether soiled or pastured is one of the most valuable grasses for cattle. It is evidently a natural grass of the country and uniformly appears in our meadows south of the city when closely nibbled by sheep or cattle and a gentleman who has traveled much through the hostile Indian country says he has seen fields covered with this grass. The report therefore as stated by Mr. Strickland to prevail among the Indians that this plant is not to be met with but where the white men have trodden must be without foundation.

The proof is incontestable that both plants were "back in the woods" as far as Ohio and Kentucky more than forty years before Strickland's visit.

Barton,[15] in 1818, writes:

> Poa pratensis; Common spear grass, introduced and naturalized, being found everywhere in grassy fields, perennial June.

Gold,[16] writing from Massachusetts in the same year to the American Farmer, stated that he understood "Green sward or English grass was native of New England" and similar statements were made about 1820–28 in the New England Farmer and The Plough Boy. There were several botanical publications issued in the early part of the nineteenth century but their chief value in connection with this study is in confirming the meaning of the numerous common names used by earlier writers.

The editor of the Massachusetts Agricultural Repository and Journal in 1821 says:

> We would observe that the application of these names in New England, to those two grasses (herds grass to *Phleum pratense* and red-top to *Poa pratensis*) is of very ancient date, having been published with us more than half a century since.

After summing up all the references to these plants, the evidence, so far as it relates to the Atlantic States, strongly corroborates the assumption that both were introduced. The earliest settlers make no mention of finding either of these plants growing here, which they should have had no trouble in recognizing because they were both well known in England at that time. The earliest reference to them relates to their being sown on cleared fields. The oldest common name applied to *Poa pratensis* is "English." All of these facts indicate their European origin. If these plants are natives of America, they were not present in sufficient quantity along the coast to make their seeding unnecessary by the earliest settlers, although one hundred years later they were present in great abundance, even to the extent in the case of *Poa pratensis* of being considered by some a pest.

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[14] Mease, James. Willrich's Domestic Encyclopedia. First American edition edited by Dr. James Mease. 1804.

[15] Barton, W. P. C. Compendium Floræ Philadelphicæ, 1: 58. Philadelphia, 1818.

[16] Gold, Thomas. *In* The American Farmer, v. 9, no. 48, p. 377.

References to the Region West of the Appalachians.

How these plants came into the region west of the Appalachian Mountains and east of the great prairie section is an interesting subject for speculation. The conditions there were somewhat different from those along the Atlantic seaboard. There were forests of large trees interspersed with open meadows. It is difficult to account for these open areas, often surrounded by dense forests. George Washington in his "Journal" kept on his famous trip to Fort du Quesne in 1753 states:

> We passed over much good land since we left Vernango and through several extensive meadows, one of which, I believe, was nearly four miles in length and considerably wide in some places.

Gist,[17] describing his first view of central Kentucky from Pilot Knob, says:

> We saw a fine level country as far as our eyes could behold and it was a very clear day.

Boone[18] similarly states:

> I beheld the ample plains the beauteous tracts below.

and in another place he says:

> The buffalo were more frequent than I have seen cattle in the settlements, browzing on the leaves of the cane or cropping the herbage of those extensive plains, fearless because ignorant of the violence of man. Sometimes we saw hundreds in a drove and the numbers about the salt springs were amazing.

These open meadows appear to have been numerous not only in Kentucky but in Indiana, Ohio, and central Pennsylvania. They are mentioned here because if bluegrass and white clover were not natives of America these open areas must have aided greatly in their early distribution.

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[17] Gist, Christopher. Journal Filson Club Publication, no. 13.

[18] Boone, Daniel. Autobiography edited by John Filson.

The first Englishman to penetrate the present state of Kentucky of whom there is any authentic record was Dr. Thomas Walker,[19] of Virginia, in 1749. He traveled by the way of southwest Virginia and Tennessee and through Cumberland Gap, and returned across the mountains to Staunton, Va. Walker did not see central Kentucky and the only reference to grass found in his journal was the mere statement, written while he was near Reedy Creek, Tenn., that the "Grass is plenty in the low grounds." In another place he stated "clover and hop-vines are plenty here."

Christopher Gist, of North Carolina, in 1750, under the employ of the Ohio Land Company, explored southern Ohio and Kentucky and returned through the mountains to the settlement in southwest Virginia. In his journal, written when he was about 30 miles north of the present site of Dayton, Ohio, he mentions the "natural meadows covered with wild rye, bluegrass and clover abounds with turkeys, deer, elk, and most sorts of game, particularly buffaloes." Jared Eliot had used the term "blue grass" previous to this, but it was doubtful from the context whether Eliot was referring to *Poa compressa* or *Agropyron repens.* It is reasonable to suppose that the term blue grass was in common use at that time. It was applied to *Poa compressa* by such botanists as Mease,[20] Pursh,[21] Barton,[22] Muhlenberg,[23] Darlington,[24] Torrey,[25] and Eaton,[26] in the early part of the nineteenth century, but the term appears to have been applied to *Poa pratensis* in Kentucky from its earliest settlement.

James Nourse,[27] who went to Kentucky in 1775, described the timber he found and says:

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[19] Walker, Thomas. Journal Filson Club Publication, no. 13.

[20] Mease, James. A Geological Account of the United States. 1807.

[21] Pursh, Frederick. Flora Americæ Septentrionalis. London, 1814.

[22] Barton, W. P. C. Loc. cit.

[23] Muhlenberg, Henry. Descriptio Uberior Graminum et Plantarum Calamariarum Americæ Septentrionalis. Philadelphia, 1817.

[24] Darlington, William. American Weeds and Useful Plants. New York, 1859.

[25] Torrey, John. A Compendium of the Flora of the Northern and Middle States. New York, 1826.

[26] Eaton, Amos. Manual of Botany for the Northern and Middle States. Albany, 1824.

[27] Nourse, James. Journal, published by M. C. N. Lyle, Lexington, Ky., p. 13.

> The growth of grass under amazing—blue grass and white clover. Buffalo grass and reeds knee and waist high! What would be called a fine swarth of grass in cultivated meadows and such was its appearance without end.

Boone's[28] first trip to Kentucky was in 1769 as a hunter. He did not move his family there until 1775. Henderson,[29] under whose auspices the Boone settlement was made, wrote a journal of the trip to "Cantuckey," 1775, in which he describes an elm, stating:

> This tree is placed in a beautiful plain surrounded by a turf of fine white clover.

Filson,[30] the biographer of Boone, wrote in 1784 of the region along the Kentucky River:

> This great tract is beautifully situated covered with cane, wild rye, and clover.

Imlay,[31] writing from Kentucky in 1792, says:

> Our other principal sorts of natural grasses are the buffalo, orchard, spear, blue and crab grass. . . . The later kinds generally spring up after the land has been cultivated and form excellent pastures and are also capable of being made into hay, particularly the spear and blue grasses.

Again he says:

> The clover is in no respect different from the clover in Europe but as it is more coarse and luxuriant.

Rev. James Smith,[32] Thomas Cooper,[33] Isaac Monsison,[34] and Col. Geo. Croghan,[35] all travelers in Kentucky prior to 1794, made similar statements in regard to the grass and clover which they found there.

That the pastures of Kentucky are of very ancient origin is well attested by the immense numbers of deer, elk, and buffalo which existed there. Traces of great roads, worn down by these animals while traveling to the salt springs, persist to this day. There have also been found large quantities of mastodon, deer, and elk bones around these salt springs, sometimes as much as 15 feet below the surface of the ground, notably those at the Blue and the Big Bone licks.

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[28] Boone, Daniel. Autobiography edited by John Filson.

[29] Henderson, —. Original in Library of Wisconsin State Historical Society.

[30] Filson, John. The Discovery, Settlement, and Present State of Kentucky.

[31] Imlay, —. Description of the Western Territory of North America, p. 234.

[32] Smith, Rev. James. Ohio Historical Society Quar., vol. 16, p. 348.

[33] Cooper, Thomas. Letters from America.

[34] Monsison, Isaac. American Museum, v. 5, p. 59.

[35] Croghan, Col. Geo. Journal, Reprint, 1831, p. 19.

There seems to be little doubt from these references that both bluegrass and white clover preceded the English settlers to Ohio and Kentucky and were there in great abundance. Of course, more than one hundred years had elapsed after these plants had been seeded along the Atlantic coast before Kentucky was explored. They may have gradually come in during that time, being creeping plants which seed abundantly. The open meadows and fertile soils offered conditions especially favorable for this dissemination. Indian traders had penetrated Tennessee and probably Ohio before the trips of Walker and Gist. These men, however, were not of the kind that usually introduce forage crops. As there were no Indian settlements in what is now Kentucky when first explored, traders could hardly have been responsible for their introduction there.

That these plants could spread readily without the aid of the white man is shown from a reference to them in connection with the "Genesee Tract." The "Genesee Tract" in western New York was ceded to the United States by the Six Nations and opened for settlement in 1788. The report of the Deputy Marshal of New York for 1791 says in regard to this tract:

> There can be no doubt but that the rearing of cattle and hogs as well as horses for sale in the low countries will soon become a great object of profit to the settlers. As the extensive range of meadow ground on the flats and the blue grass, white clover and pea vine in the woods must enable the farmer to feed almost any number he can raise or find capital to purchase. In many parts of the tract there is little or no underwood and excellent pasture in the forests between the trees in consequence of their being of enormous size and of the considerable distance between them.

The most reasonable explanation of the introduction of bluegrass and white clover into the Ohio Valley is that they were carried there by the French. Frequent expeditions were made by the French settlers and missionaries from Canada to the Illinois country after the discovery and exploration of the Mississippi River by Marquette and La Salle, 1672 to 1682. A fort and settlement was made at Kaskaskia on the Kaskaskia River about 1700 and at Vincennes on the Wabash in 1702. Charlevoix[36] reports finding thriving settlements at those places when he visited them in 1721. He also men-

[36] Charlevoix, P. F. X. de. Histoire et Description Generale de la Nouvelle France. Paris, 1744.

tions their having poultry and black cattle. The introduction of forage crops and live stock has usually been simultaneous.

The French missionaries in their efforts to civilize the Indians often distributed seeds among them. Charlevoix speaks of Saint Denys giving the Indians along the lower Mississippi "both agricultural implements and seed to sow." The following quotation from Kalm,[37] written in 1749, indicates that bluegrass and white clover were the most important hay-making plants of the French in Canada:

> The high meadows in Canada are excellent. . . . The further I advanced northward here the finer were the meadows and the turf upon them was better and closer. Almost all the grass here is of two kinds; viz., a species of the narrow-leaved meadow grass (*Poa angustifolia*) for its spikes contain either three or four flowers which are exceedingly small that the plant might easily be taken for a bent grass (*Agrostis*) and its seeds have several small downy hairs at the bottom. The other plant which grows in meadows is the white clover (*Trifolium repens*). These two plants form the hay in meadows; they stand close and thick together and the meadow-grass (*Poa*) is pretty tall but has very thin stalks. At the root of the meadow grass the ground was covered with clover, so that one can not wish for finer meadows than are found here. Almost all the meadows have been formerly corn fields as appears from the furrows on the ground which still remain.

The limestone soils of the Ohio Valley, which were often liberally supplied with phosphates, offered favorable conditions for the growth of these plants. Both are aggressive, the seeds of both are easily disseminated, and so it does not task our imagination to suppose they could have become widely distributed in the half century which elapsed from the settlements of the French to the explorations of the English in that region.

CONCLUSIONS.

The references here given all point to the probability, as well as the possibility, that both Kentucky bluegrass, *Poa pratensis,* and white clover, *Trifolium repens,* were introduced into America. This evidence, together with the fact that botanists have not been able to trace their range of entry through the two natural routes of Labrador and Alaska as they have that of almost all other plants known to be natives of both Eurasia and America, appears to be conclusive. The only reason for considering them natives of America seems to be based on the rapid manner in which they spread on fertile limestone soils and the wide dissemination of their seeds through forests, where they flourish as soon as the land is cleared.

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[37] Kalm, Per. *In* Pinkerton's Voyages and Travels. London, 1819.

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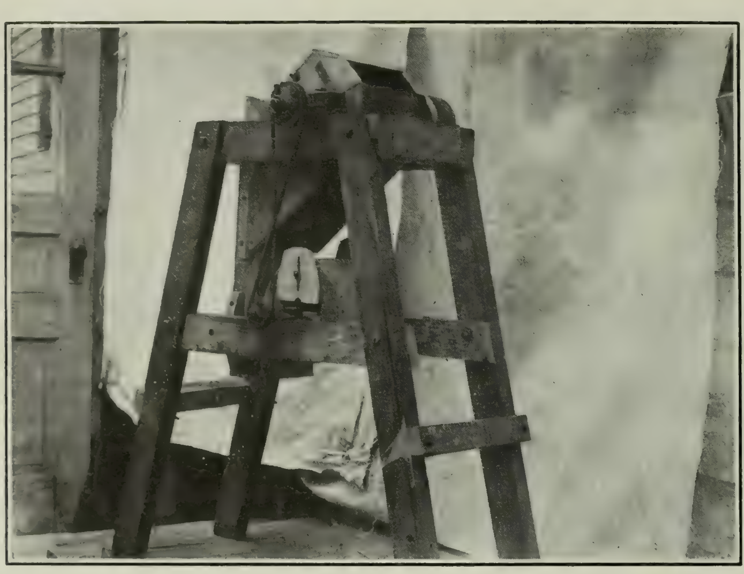

FIG. 1. Front and side view of the machine designed for thrashing single heads of the small grains.

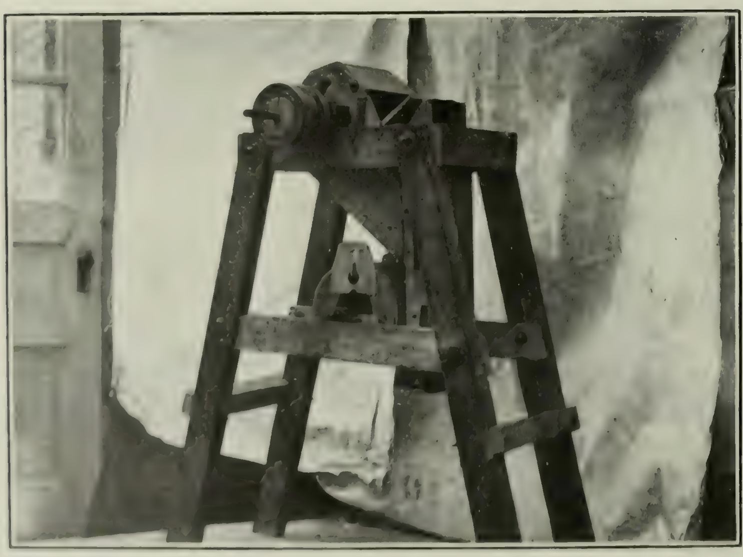

FIG. 2. Rear and side view of the head or plant small-grain thrasher.

AN EFFECTIVE HEAD THRASHER.[1]

W. E. HANGER,

MARYLAND AGRICULTURAL EXPERIMENT STATION, COLLEGE PARK, MARYLAND.

For several years past one of the important lines of work at the Maryland station has been the breeding of wheat and oats by hybridization and by head or plant selection. Although the importance of working with large numbers has been fully appreciated, the great amount of hand labor involved in thrashing the single heads has always proven a formidable obstacle. With the idea of eliminating the tedious process of rubbing out the single heads by hand and thus reducing to a minimum the amount of labor involved in carrying on this line of work, the agronomy department of the station designed and constructed during the summer of 1913 a small head thrasher that has given excellent results. This thrasher may be driven by a small gasoline engine or electric motor.

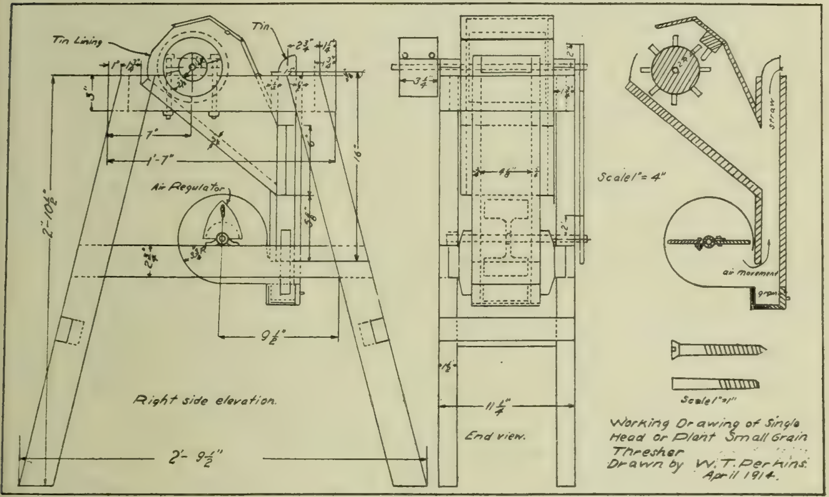

FIG. 9. Working drawing of single head or plant small-grain thrasher, showing details of construction.

The accompanying illustrations (Plate IX and fig. 9) give a good idea of the general design of the thrasher and the details of its con-

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[1] Received for publication April 11, 1916.

struction. The cylinder, which is 6½ inches long and 4 inches in diameter, is made of a solid piece of wood. The teeth are made of 2-inch screws with the heads cut off and flattened, after which they are screwed into the cylinder. There are eight rows of teeth in the cylinder, rows of 5 teeth alternating with rows of 7 teeth. The concaves, constructed in the same manner and consisting of two rows of teeth, are placed above and a little to the back of the center of the cylinder, so that no place is allowed for grain to lodge.

As a precaution against grain lodging between the ends of the cylinder and the frame of the machine, a space of ¼-inch is provided at each end of the cylinder. The cylinder is mounted in a box in such a way that the grain and chaff slide down the very steep bottom into an air chute, where they meet a blast of air sufficiently strong to carry the chaff upward and out of the chute, but which allows the grain to drop to the bottom into a small tray. The fan for the thrasher is run by a belt driven from the cylinder shaft.

It sometimes happens that a straw is jerked out of the feeder's hand and lodges back of the cylinder on the bottom of the cylinder box. In order that these straws may be removed without stopping the engine or motor, a door large enough to insert one's hand is provided back of the cylinder. This door is a precaution which should not be neglected, for it also provides a means of removing any straws that may lodge, without danger of having the hand caught in the rapidly revolving cylinder.

To secure the greatest efficiency in operating the thrasher, four men are required. The first feeds, holding the straw so that only the head is allowed to reach the cylinder; the second withdraws the tray into which the grain has fallen and empties it into a funnel that is supported by a ringstand; the third opens the small envelopes and holds them at the bottom of the funnel to receive the grain; and the fourth is kept busy sealing the envelopes. With this thrasher operated in the manner described it has been found easily possible to thrash and seal into envelopes from 800 to 1,000 heads per hour.

AGRONOMIC AFFAIRS.

MEETINGS OF THE SOCIETY.

Attention is again called to the two meetings of the American Society of Agronomy which are to be held during the next few months. The first is a sectional meeting at Amarillo, Tex., on August 22–24, in joint session with the Great Plains Cooperative Association. Agronomists in the Great Plains section are particularly urged to attend and to participate in the program. The second is the annual meeting of the Society, which will be held in Washington, D. C., on Monday, November 13, and Tuesday, November 14, 1916. A call for the titles of papers for presentation at both these meetings was mailed about June 15. Those who have papers to present and who have not already communicated with the Secretary regarding them are urged to do so at the earliest opportunity, in order that the programs of these meetings may be made up at as early a date as possible.

MEMBERSHIP DUES FOR 1916.

Those members who have not yet paid their dues for 1916 will greatly facilitate the work of the treasurer if they will remit to him promptly. Statements were sent to all members early in the year. The mailing of duplicate statements entails unnecessary expense to the society as well as needless work for the treasurer. If you have not already remitted, write a check now for two dollars, payable to "Treasurer, American Society of Agronomy," and mail it to Prof. George Roberts, Experiment Station, Lexington, Ky.

MEMBERSHIP CHANGES.

The membership reported in the last number was 562. Since that time 1 member has resigned and 9 new members have been added, making the net membership at this time 570. The names and addresses of the new members, the name of the member resigned, and recent changes of address which have been reported, follow. Three resignations were reported in the May–June number, but only two names were published. The one omitted is included in the present list.

New Members.

Hall, E. W., County Agent Spink Co., Redfield, S. Dak.
Hill, W. H., Agricultural College, Guelph, Ontario.

Karlstad, C. H., Agricultural College, Brookings, S. Dak.
Schneiderhan, F. J., Eastern Oregon Dry-Farming Substa., Moro, Oreg.
Sink, Stanley B., College of Agriculture, Orono, Maine.
Tabor, Paul, College of Agriculture, Athens, Ga.
Vanatter, P. O., College of Agriculture, Athens, Ga.
West, J. T., Agricultural College, Miss.
Winwright, George, Agricultural College, Brookings, S. Dak.

MEMBERS RESIGNED.

Robert J. Leth, Samuel L. Sloan.

ADDRESSES CHANGED.

Carnes, Homer M., North Powder, Oreg.
Hall, Thos. D., College of Agr., Potchefstroom, Union of South Africa.
Holland, Robt. E., County Agent Kimball Co., Kimball, Nebr.
Macfarlane, Wallace, Agricultural College, Stillwater, Okla.
Musback, Fred L., Marshfield, Wis.
New, T., Tsing Hua College, Peking, China.
Plummer, J. K., P. O. Box 204, Raleigh, N. C.
Wheeler, Clark S., 423 W. Ninth St., Columbus, Ohio.
Yoder, P. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.

NOTES AND NEWS.

C. H. Bailey, cereal technologist in the Minnesota station, has been granted a year's leave of absence for research work in the laboratory of the State Grain Inspection Department in Minneapolis.

E. D. Ball, director of the Utah experiment station and school of agriculture, resigned at the close of the college year. F. S. Harris, agronomist, has been elected director of the experiment station, and G. R. Hill, jr., professor of botany and plant pathology, director of the school of agriculture. John T. Caine, III, has succeeded E. G. Peterson as director of extension work, the latter having been elected president of the Utah college. R. J. Evans is assistant director of extension and Lorin A. Merrill, assistant state leader.

P. B. Barker, associate professor of field crops in the extension service of the University of Missouri, is now head of the department of agronomy of the University of Arkansas.

H. M. Carnes, research assistant in farm crops at the Oregon station, has resigned to engage in farming at North Powder, Oreg., and has been succeeded at the station by H. A. Schoth.

W. Davison, of the Prince Edward Island department of agriculture and a member of the American Society of Agronomy, is with the Canadian expeditionary force "at the front."

A. W. Drinkard, jr., associate horticulturist, has been elected director of the Virginia station.

B. T. Galloway, dean of the college of agriculture and director of the experiment station at Cornell University, has resigned, effective July 1.

A. W. Gilbert, professor of plant breeding at Cornell University, has resigned to pursue graduate study.

Angus Gordon has succeeded D. S. Myer as instructor in agronomy in the University of Kentucky.

Thos. D. Hall has been appointed assistant chemist in the college of agriculture, Potchefstroom, Union of South Africa.

S. B. Haskell, assistant agronomist of the Massachusetts college, resigned July 1 to engage in commercial work.

H. C. Head became assistant agronomist at the Arizona station on March 1.

The new agricultural building now under construction at the University of California has been named Hilgard Hall, in honor of the late E. W. Hilgard, for many years professor of agriculture and dean of the college of agriculture of the university.

R. E. Holland has resigned as assistant in instructional agronomy in the University of Nebraska to become county agent of Kimball County, with headquarters at Kimball, Nebr.

B. H. Hunnicutt, director of the school of agriculture at Lavras, Minas, Brazil, was also director of the Second National Corn Show for Brazil, which was held at Belle Horizonte, Minas, on July 19 to 21. The expenses of the show were paid by a monthly agricultural paper, "Chacaras e Quintaes," and by a subsidy from the State of Minas. Director Hunnicutt has been influential in organizing the Brazilian National Corn Club, of which Dr. J. F. de Assiz Brazil is the president.

C. B. Hutchison, professor of farm crops in the University of Missouri, has accepted a professorship in the plant breeding department of the college of agriculture of Cornell University. He will enter on his duties there in 1917, after a year of graduate study at Bussey Institute.

O. W. Israelson, instructor in irrigation in the University of California, has been appointed assistant professor of irrigation in the Utah Agricultural College. D. W. Pittman has been appointed assistant agronomist in the same institution.

Jesse M. Jones of the Office of Farmers' Cooperative Demonstration Work in the Southern States, U. S. Department of Agriculture, has been elected director of extension work at the Virginia Polytechnic Institute.

Frank S. Kedzie, who, as noted previously, has been acting president of the Michigan Agricultural College since September, 1915, was elected president of the college in April. Dr. Kedzie graduated from the Michigan college in 1877, and has been connected with it almost continuously since, most of the time as professor of chemistry.

C. A. LeClair, assistant professor of soils in the Missouri college, has resigned to engage in commercial work. J. C. Hackleman, assistant professor of farm crops, has been transferred to the extension service.

W. A. Lintner, assistant professor of agronomy in Delaware College and assistant agronomist of the Delaware station, has resigned to go into commercial work.

J. H. Lloyd, instructor in agronomy in Purdue University, has been appointed agricultural advisor in Hancock County, Ill.

At the June commencement of the University of Missouri the degree of Doctor of Laws was conferred on C. F. Marbut, in charge of the soil survey of the U. S. Department of Agriculture.

K. Miyake, assistant professor of agricultural chemistry in the College of Agriculture, Tohaku, Imperial University, Sapporo, Japan, who has been pursuing studies in physical and biological chemistry in the University of California during the past year, is now engaged in further studies in soil chemistry in the laboratories of the Department of Agriculture at Washington, D. C.

T. New, who has been pursuing post-graduate studies in soils at Cornell University, is now connected with Tsing Hua College, Peking, China.

W. C. Riddick, professor of civil engineering in the North Carolina Agricultural and Mechanical College, has been elected president of the institution, succeeding Dr. D. H. Hill, who, as previously reported, has resigned.

A. Z. Smith has been appointed assistant agronomist at the New Mexico station.

B. M. Stubblefield has been appointed assistant in soils at the Ohio station.

The Second Interstate Cereal Conference met at St. Paul, Minn., July 11, 12, and 13. A meeting of agronomists in the Western states was held at Logan, Utah, July 18, 19, and 20. Brief reports of both these meetings will be included in the next number of the JOURNAL.

Local sections of the American Society of Agronomy have recently been organized at the Georgia State College of Agriculture, Athens, Ga., and the South Dakota Agricultural College, Brookings, S. Dak.

JOURNAL

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American Society of Agronomy

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FIELD TESTS OF FERTILIZER ACTION ON SOIL ALDEHYDES.[1]

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SOIL FERTILITY INVESTIGATIONS, U. S. DEPARTMENT OF AGRICULTURE,

AND

C. F. NOLL,

AGRONOMY DEPARTMENT, PENNSYLVANIA EXPERIMENT STATION.

INTRODUCTION.

Aldehydes have been found to occur in a number of soils. Such soils are usually unproductive.[2] Salicylic aldehyde was first found in a soil from Mt. Vernon, Va.,[3] and vanillin in a soil from Florida.[4] Since then vanillin has frequently been isolated from soils.

Field tests with vanillin and salicylic aldehyde were made in 1913, and the results show that they were harmful to cowpeas, string beans, and garden peas grown in an unproductive silty clay loam on the Arlington Farm, Va.[5] This investigation has been extended and tests of these compounds were made again in 1914 and 1915 at Arlington Farm, and also on the Hagerstown loam at the Pennsylvania Experiment Station. This experiment was made to study the effects in soils of different characteristics, and also to study the influence of lime and certain fertilizers on the action of these compounds.

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[1] The work at the Pennsylvania Experiment Station was done jointly by C. F. Noll and J. J. Skinner. The chemical tests and the work at Arlington Farm were conducted by J. J. Skinner. Received for publication May 19, 1916.

[2] Schreiner, O., and Skinner, J. J. Harmful Effects of Aldehydes in Soils. U. S. Dept. Agr. Bul. 108. 1914.

[3] Shorey, E. C. Some Organic Soil Constituents. U. S. Dept. Agr., Bur. Soils Bul. 88, p. 19. 1913.

[4] Shorey, E. C. The Presence of Some Benzene Derivatives in Soils. U. S. Dept. Agr., Jour. Agr. Research, 1: 357. 1914.

[5] Skinner, J. J. Field Tests with a Toxic Soil Constituent: Vanillin. U. S. Dept. Agr. Bul. 164. 1915. Schreiner, O., and Skinner, J. J. Harmful Effects of Aldehydes in Soils. U. S. Dept. Agr. Bul. 108. 1914.

Salicylic aldehyde ($C_6H_4OH \cdot COH$) occurs in some plants, in several species of *Spiraea*[6] and in *Fœtida*.[7] It is harmful in solution in very small amounts, as has been demonstrated with wheat, corn, cowpeas, cabbage, and rice. In nutrient solutions of calcium acid phosphate, sodium nitrate, and potassium sulfate the harmful effects were least noticeable in the cultures high in phosphate. In soil in pots it was also shown to be harmful to wheat, corn, and clover.[8]

Vanillin ($C_6H_3 \cdot OCH_3 \cdot OH \cdot COH$), methyl protocatechuic aldehyde, is the aromatic principle of the vanilla bean. It has been found in the seeds and roots of a number of plants and in rotten oak wood, which has led to the conclusion that its origin in soils is from vegetable debris.[9] Vanillin is harmful to wheat seedlings in water cultures, even in such low concentration as a few parts per million, and the plants are killed in a solution of 500 p. p. m.[10] Vanillin is also harmful in nutrient solutions composed of phosphate, nitrate, and potash. It is an oxidizable substance and is less harmful in certain solutions of nutrient salts than in others, especially those high in nitrate.[11] Sodium nitrate and calcium carbonate,[12] which promote oxidation in plants and soils, ameliorate the harmfulness of vanillin.

Vanillin was harmful to wheat in pots when added to an infertile Florida sand and to an unproductive Susquehanna sandy loam, but had no harmful action when added to a productive Hagerstown loam.[13] This indicated that vanillin acts differently in different soils, a conclusion which has been sustained by subsequent work in a considerable number of soils in pots and also in the field. The reasons for this will be made clear in the present and in following papers and will show the errors made in the deductions of Davidson and the correctness of the assumption made by Upson and Powell.

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[6] Ettling. Ann. Chem., 35: 247 (1838); Wicke, ibid., 83: 175 (1855).

[7] Wicke. Ann. Chem., 91: 374 (1856).

[8] U. S. Dept. Agr. Bul. 108.

[9] Sullivan, M. X. Jour. Ind. and Eng. Chem., 6: 119 (1914). See also de Routon, Compt. Rend., 125: 797 (1897); Campani and Grimaldi, Chem. Centr., 1: 377 (1888); Von Lippman, Ber. Chem. Ges., 18: 3335 (1885); Scheibler, Ber. Chem. Ges., 13: 335 (1880).

[10] Schreiner, O., Reed, H. S., and Skinner, J. J. Certain Organic Constituents of Soils in Relation to Soil Fertility. U. S. Dept. Agr., Bur. Soils Bul. 47. 1907.

[11] Schreiner, O., and Skinner, J. J. Organic Compounds and Fertilizer Action. U. S. Dept. Agr., Bur. Soils Bul. 77. 1911.

[12] Schreiner, O., and Reed, H. S. The Power of Sodium Nitrate and Calcium Carbonate to Decrease Toxicity in Conjunction with Plants Growing in Solution Cultures. Jour. Amer. Chem. Soc., 30: 85. 1908.

[13] U. S. Dept. Agr. Bul. 164.

Davidson[14] made some experiments with the effect of vanillin on wheat grown in pots in Dunkirk clay loam. He obtained practically no effect with added amounts of vanillin less than 1,000 p.p.m. With vanillin used in amounts of 1,000 p.p.m. without fertilizer a depression of 10 percent in growth resulted, and the effect with the soil limed was about the same; with fertilizers the results were irregular. No attempt was made to determine if the added vanillin remained in the soil or whether it was changed or destroyed. Upson and Powell,[15] working with a black silt loam of excellent texture and rich in organic matter, found vanillin had no effect on the growth of wheat, and with another soil of equally good texture but less productive vanillin depressed growth only slightly. Salicylic aldehyde in the same soil depressed growth slightly. They conclude that aeration and absorption are important factors in overcoming the effect of the aldehydes, but give no experimental evidence. They explain their results by the fact that their soil was one of loose texture, permitting aeration and oxidation. They, likewise, made no attempt to ascertain whether vanillin or salicylic aldehyde existed in their soil for any length of time or whether it was destroyed.

Fraps,[15a] on the other hand, found that vanillin diminished more or less rapidly in the Texas soils which he studied. In his cultural work he supplied the vanillin in some of his experiments in fractional parts to the soil during the growth of the plant. In practically all cases the growing plants were injured except in the lower concentration of 100 p. p. m. Periodical application of this concentration injured the plants but did not kill them in the case of these soils in which vanillin disappeared rapidly. An examination of his results shows that the more rapid and complete the loss of vanillin in the soil the less is the injury observed on the growing plant. Thus his soil No. 3346 with vanillin showed a decrease in plant growth of about 27 percent and a loss of vanillin in two weeks' time of only 24 percent; soil No. 4747 with vanillin showed a decrease in plant growth of about 14 percent and a loss of vanillin in two weeks' time of 60 percent; soil No. 4605 with vanillin showed a decrease of only 6 percent in growth but a loss of 71 per cent in vanillin in two weeks' time.

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[14] Davidson, J. A Comparative Study of the Effect of Cumarin and Vanillin on Wheat Grown in Soil, Sand and Water Cultures. JOUR. AMER. SOC. AGRON., 7: 145–158 and 221–238. 1915.

[15] Upson, F. W., and Powell, A. R. The Effect of Certain Organic Compounds on Wheat Plants in the Soil. Jour. Ind. and Eng. Chem., 7: 420. 1915.

[15a] Fraps, G. S. The Effect of Organic Compounds in Pot Experiments. Texas Agr. Expt. Sta. Bul. 174. 1915.

In the plot work at Arlington Farm in 1913 the vanillin and salicylic aldehyde were not destroyed or changed in this soil, for the aldehydes could be isolated from the soil six months after their addition. They persisted in this soil throughout the growing season, perhaps even longer. In water culture experiments vanillin and certain other harmful organic compounds were changed by oxidation and their harmfulness overcome. Sodium nitrate and calcium carbonate were found to partially overcome the effects of vanillin. The effects of such compounds in soils seem to depend upon the geological origin, chemical nature, and biological activities of the soil.

The present paper gives the results of a field test of vanillin and salicylic aldehyde on two soils, differing in origin and in physical, biological, and chemical characteristics. On one of these soils, which has small producing qualities, how oxidative power, and is naturally an acid soil, vanillin and salicylic aldehyde were harmful when added in amounts of 300 and 150 pounds per acre, respectively. The aldehydes were found to persist in this soil for some time. On the other soil, which is naturally fertile, has strong oxidizing power and is derived from residual limestone, vanillin and salicylic aldehyde had only a slight effect in decreasing crop yield. The aldehydes were found not to remain in this soil for any length of time.

Sodium nitrate was found to ameliorate the harmful effect of vanillin, and acid phosphate the harmfulness of salicylic aldehyde. Lime overcame the effect of both compounds. Vanillin did not remain in the soil fertilized with sodium nitrate and neither aldehyde persisted in the limed soil. It is apparent then that the effect of such organic compounds would be different under different soil conditions.

The effect of these two compounds on growth in a large number of soil types was also determined by growing plants in pots. It was found that the effect varies with the soil used. These results will be presented and discussed in another paper and are merely mentioned here to show their bearing on this behavior of aldehydes in soils of different character and properties.

EFFECT OF ALDEHYDES ON SUSQUEHANNA SILTY CLAY LOAM.

Experiments with vanillin and salicylic aldehyde were made on Arlington Farm in 1913 with several crops. In 1914 and 1915 these tests were confined to the growth of cowpeas, but the soil treatments were enlarged upon so as to determine the effect of soil aldehydes in soil to which lime and certain fertilizers were added. Slightly larger amounts of both vanillin and salicylic aldehyde were used in this test than in the test with the three crops in 1913. At that time vanillin was used at the rate of 285 pounds per acre and salicylic aldehyde at the rate of 105 pounds per acre. In 1914 and 1915 vanillin was used at the rate of 300 pounds per acre and salicylic aldehyde at the rate of 150 pounds per acre.

The plan of the experiment is shown in figure 10. Both vanillin and salicylic aldehyde are added to the soil (1) without fertilizers, (2) with sodium nitrate, and (3) with acid phosphate. The aldehydes are also applied to limed soil, with no fertilizers, with sodium nitrate, and with acid phosphate. It is seen that there are two unfertilized checks to compare with the vanillin and salicylic aldehyde plots. There are two check plots treated with sodium nitrate to compare with the plots which received vanillin or salicylic aldehyde in addition to sodium nitrate; and there are two check plots which received acid phosphate to compare with the plots which received vanillin or salicylic aldehyde in addition to the acid phosphate. These treatments are repeated on an adjoining strip of ground which had been previously limed at the rate of 2 tons per acre.

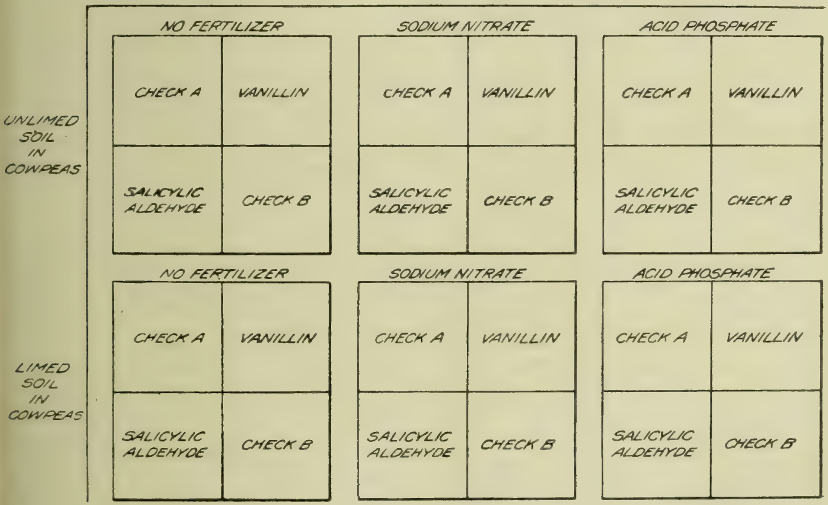

FIG. 10. Plan of soil aldehyde experiment.

Each of these blocks of four plots as shown in the diagram is 1 square rod, making each small plot 1/640 acre.

As stated above, vanillin was applied at the rate of 300 pounds per acre and salicylic aldehyde at the rate of 150 pounds per acre. Sodium nitrate was added in amounts of 180 pounds per acre and acid phosphate at the rate of 360 pounds per acre. The method of applying these substances was to apply one third of the total amount before planting, one third when the plants were about 4 inches high, and the remaining one third about four weeks after the second application. The vanillin and salicylic aldehyde were dissolved in water and the portion applied before planting was sprinkled uniformly over the surface of the plot and well incorporated in the soil by raking with a long-toothed rake. The remaining applications were made by hoeing a trench 4 to 5 inches deep on each side of the row of peas, about 4 inches from the row. After adding the dissolved aldehyde, it was covered by pulling the soil back into the trench with a hoe. The fertilizers were applied at the same time and were broadcasted over the plot and raked in. The total amount of lime on the limed plots was applied two weeks before the experiment was started. This was used at the rate of 2 tons per acre. It was spaded in and well mixed with the soil to a depth of 8 inches.

The soil on which the experiment was made is a heavy silty clay loam, low in organic matter. It is classified in the Susquehanna series. It is naturally an unproductive soil but can be made to produce fair crops by manuring heavily with green manures or stable manure, and responds to fertilizers well when limed. It is acid and when the surface soil is neutralized it becomes acid again within a few months, whether growing crops or fallowing. The ground on which the plots are laid out is level, has surface drainage and is fairly uniform, so the differences in crop growth can safely be considered as due to treatments and not to non-uniformity of soil.

THE RESULTS OBTAINED IN 1914.

Four rows of cowpeas were planted on each plot, May 20, 1914. The Early Buff, an early maturing variety, was used. The first portion of vanillin, salicylic aldehyde, and fertilizers was applied May 20, before seeding; the second application was made June 6, when the plants were up 3 to 4 inches; and the third and last application was made July 16. The seeds germinated well and came up uniformly. In the early stages of growth the plots showed slight differences and notes taken July 16, preceding the last application, are here given.

NOTES ON GROWTH.

Unfertilized Section.—The two check plots have made a growth of about 22 inches in height. The plants have a good dark green color; they are beginning to put out runners. No blooms are appearing.

The plants on the vanillin-treated plot are stunted in growth; they are one half to one third the size of the check-plot plants; average height about 12 inches. There are no runners and no blooms. The vines have a pale yellow color and do not appear as hardy and thrifty as the check-plot plants. The leaves are distorted, are curled unnaturally and the ribs are more prominent.

The salicylic aldehyde plot has produced plants of about the size, or slightly smaller than, the vanillin plot. The average height is about 10 inches. They have a lighter green color than the check-plot plants but are not as pale as the vanillin plot plants.

Sodium Nitrate Section.—The sodium nitrate check-plot plants are about the size of the plants in the check plots of the unfertilized section. They have a height of 20 to 22 inches. The color is good dark green. A few runners and a few blooms are out.

The vanillin-plot plants are almost as good as the sodium-nitrate-check plants; are a little smaller. The color is good and there is no sign of distorted or disfigured leaves. The average height is 18 to 20 inches. A few runners are starting.

The salicylic-aldehyde-plot plants are smaller than the check plants, about the size of the salicylic-aldehyde plants in the no-fertilizer section.

Acid Phosphate Section.—The plants in the acid phosphate check plots are the best of the series. Their height is 28 to 30 inches. The color of the vines is a dark green and they are healthy and thrifty. The plants are full of runners and have some blooms.

The vanillin-plot plants are much smaller than the checks. The difference between the check plot and the vanillin plot of the acid phosphate section is about as great as the difference between the check plot and the vanillin plot of the no-fertilizer section.

The growth in the salicylic-aldehyde plot is almost as good as in the check plots. The plants have a good color, are thrifty and healthy. There are a few runners.

Limed Soil, No-fertilizer Section.—The plants have made an excellent growth; they are tall and bushy and are full of runners and blooms. They are twice the size of the unlimed checks. The color of the foliage is a deep dark green color.

The vanillin-plot plants are about the size of the checks; they are full of runners and blooms. There is no indication of a harmful effect.

The growth on the salicylic-aldehyde plot is not quite as good as the check. The color is good.

Limed Soil, Sodium Nitrate Section.—The check-plot plants are a little better than the limed unfertilized checks, and growth is bulky and thick.

The vanillin plot is slightly smaller than the check in growth, and the runners are not so numerous. The color is good and there are no unnatural leaves.

The growth in the salicylic-aldehyde plot is about the same as in the check plot. There are many runners and blooms.

Limed Soil, Acid Phosphate Section.—The growth on the check plots is better than on the limed no-fertilizer check.

The vanillin-plot plants are slightly smaller than the check, the growth is good and plants healthy.

On the salicylic-aldehyde plot the growth is about the same as on the check plots.

There is very little difference between the plots on the limed soil. At this stage of the growth the aldehydes are apparently having no effect in the limed soil.

Photographs were taken July 16 and are reproduced in Plates X and XI. The marked differences in growth on the vanillin and salicylic-aldehyde plots are apparent. In Plate X, figures 1, 2, and 3, are shown the effect of vanillin on cowpeas in the unfertilized Susquehanna silty clay loam, the effect of vanillin on the soil fertilized with sodium nitrate, and its effect on the soil fertilized with acid phosphate. As seen in figure 1, the vanillin plants on the left have made a much smaller growth than the check plot on the right. In figure 2 the vanillin plot on the left, fertilized with sodium nitrate, has made almost as good growth as its check plot on the right. The sodium nitrate has overcome to a great extent the effect of the vanillin. In the soil fertilized with acid phosphate the growth, as shown in figure 3, is not nearly as good on the vanillin plot on the left as in its check plot on the right. The vanillin has retarded growth almost as much on the acid-phosphate plots as on the unfertilized soil.

In Plate XI, figures 1, 2, and 3, are shown the effects of salicylic aldehyde on cowpeas grown on unfertilized soil, on soil fertilized with sodium nitrate, and with acid phosphate. In figure 1 the plants on the left, which received the salicylic aldehyde, are much smaller than the check on the right. This is also true with the growth on the soil fertilized with sodium nitrate (figure 2). Here, again, the salicylic-

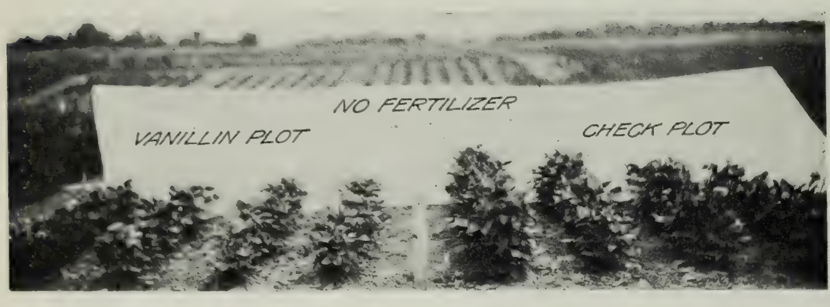

FIG. 1. Effect of vanillin on cowpeas in Arlington soil, without fertilizers (1914).

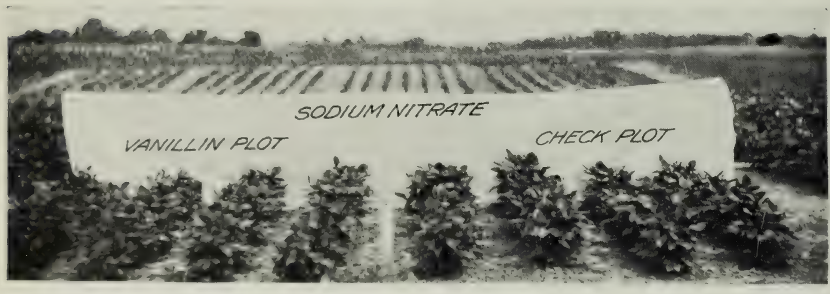

FIG. 2. Effect of vanillin on cowpeas in Arlington soil, with sodium nitrate (1914).

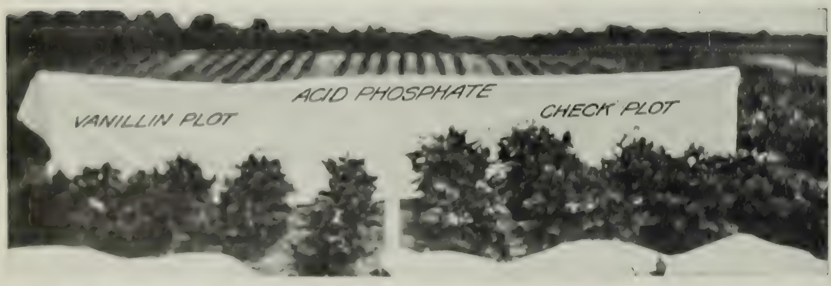

FIG. 3. Effect of vanillin on cowpeas in Arlington soil, with acid phosphate (1914).

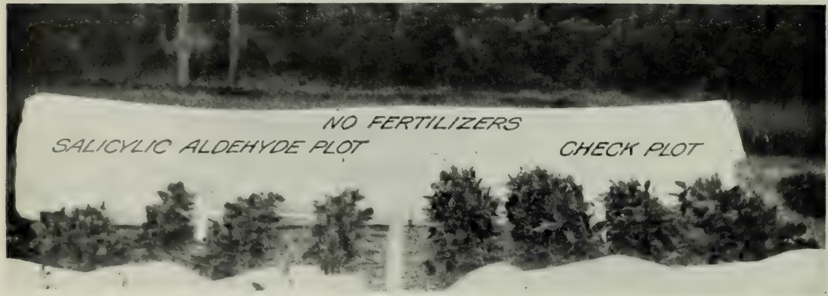

FIG. 1. Effect of salicylic aldehyde on cowpeas in Arlington soil, without fertilizers (1914).

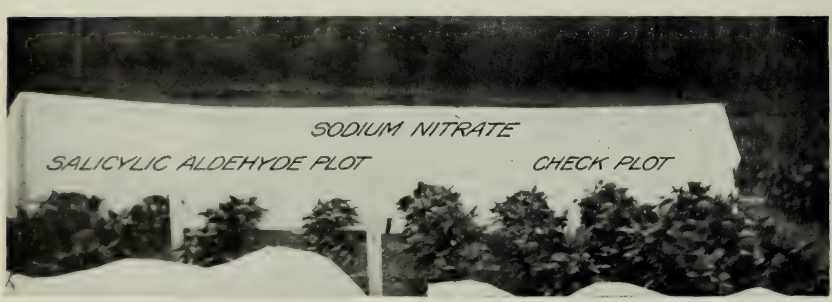

FIG. 2. Effect of salicylic aldehyde on cowpeas in Arlington soil, with sodium nitrate (1914).

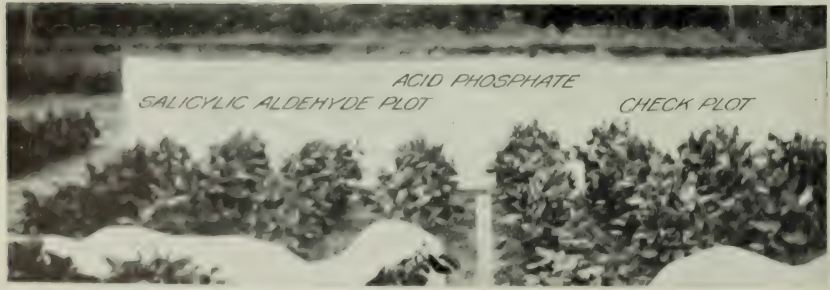

FIG. 3. Effect of salicylic aldehyde on cowpeas in Arlington soil, with acid phosphate (1914).

aldehyde-treated plants on the left are much smaller than the check plants on the right. The growth on the soil fertilized with acid phosphate is almost as good on the salicylic-aldehyde plot as on the check, as shown in figure 3. It seems from this that acid phosphate has an influence in ameliorating the harmful effect of salicylic aldehyde in this soil.

WEIGHTS OF GREEN AND CURED CROP.

The cowpeas were harvested August 19. The plants had made their full growth and the seed was ripening. The peas on the limed section were more mature than on the unlimed; the bottom leaves were turning and some were beginning to fall. The vanillin and salicylic-aldehyde plots were slower in maturing than their checks. The cowpeas were picked from the vines before they were cut and their weight in pod taken separately. The green weight of the vines was taken and then the vines were spread back upon the plot and allowed to dry. The dry weights of the cured cowpea hay were taken August 24. The results for each plot are given in Table 1.

TABLE 1.—*Effect of vanillin and salicylic aldehyde on cowpeas grown in the field on Susquehanna silty clay loam in 1914, and the action of fertilizers in modifying their effects (weights given in pounds per plot).*

Treatment.	Unlimed soil.					Limed soil.				
	Green weight.			Dry weight.		Green weight.			Dry weight.	
	Vines.	Pods.	Relative total weight.	Hay.	Relative weight.	Vines.	Pods.	Relative total weight.	Hay.	Relative weight.
No fertilizer section:										
Check *A*	21.50	6.00	100	10.00	100	26.00	9.50	100	15.00	100
" *B*	22.00	6.75		11.00		24.50	8.75		13.75	
Vanillin	13.50	4.25	67	7.50	71	23.00	9.75	107	14.25	99
Salicylic aldehyde	10.50	3.75	59	5.75	55	18.50	7.00	77	10.75	71
Sodium nitrate section:										
Check *A*	24.50	7.25	100	12.50	100	27.50	9.75	100	15.75	100
" *B*	23.25	7.50		12.25		25.75	8.50		15.00	
Vanillin	21.00	6.75	91	11.50	91	27.75	9.25	101	14.75	96
Salicylic aldehyde	15.25	4.00	54	8.75	70	22.00	7.50	83	12.50	82
Acid phosphate section:										
Check *A*	25.50	7.75	100	14.25	100	29.25	9.50	100	15.50	100
" *B*	25.00	7.25		13.75		32.00	10.00		16.25	
Vanillin	19.00	6.00	80	10.00	71	29.00	8.75	90	14.75	93
Salicylic aldehyde	23.75	7.25	97	13.00	93	29.75	9.25	95	15.50	98

An examination of the table shows that the check plots were fairly uniform; the yields on these duplicate plots were very nearly the same. An average of the two checks will be taken here in comparing the yields of the treated plots. Considering first the unlimed soil, it is seen that vanillin and salicylic aldehyde reduced growth very much in the unfertilized soil. As shown in the third column of the table, the green weight was reduced by vanillin from 100 to 67, or 33 percent, and by salicylic aldehyde from 100 to 59, or 41 percent. The weight of cured hay was reduced by vanillin from 100 to 71, a reduction of 29 percent, and by salicylic aldehyde from 100 to 55, a reduction of 45 percent.

In the plots fertilized with sodium nitrate the vanillin reduced the growth only 9 percent in both green weight and dry weight, that is, from 100 for the check to 91 for the vanillin-treated plot. The salicylic aldehyde reduced growth in green weight from 100 for the check to 54, a 46 percent decrease, and in dry weight from 100 for the check to 70, a reduction of 30 percent.

In the plots fertilized with acid phosphate, vanillin reduced the green weight from 100 for the check to 80, a reduction of 20 percent, and the dry weight from 100 to 71, a reduction of 29 percent. The salicylic aldehyde reduced the green weight from 100 for the check to 97, a reduction of only 3 percent, and in cured hay from 100 to 93, a reduction of 7 per cent.

Both of these compounds then had a harmful effect in this soil. The harmfulness of vanillin was partly overcome by sodium nitrate, but was just as harmful with acid phosphate, and the bad effects of salicylic aldehyde were partly overcome by acid phosphate, but sodium nitrate had no such helpful function.

Considering now the limed soil, given in the last half of the table, it is seen that the vanillin had no harmful effects in the unfertilized soil. The salicylic aldehyde reduced growth in green weight from 100 for the check to 77, or a reduction of 23 percent as against 41 percent for the unlimed plot. In dry weight there was a reduction of 29 percent as against 45 percent for the unlimed plot.

In the sodium-nitrate plots the growth in the vanillin plot was approximately the same as in the checks. The salicylic aldehyde reduced growth from 100 for the check to 82, a reduction of 18 percent in both green and dry weight.

In the acid-phosphate-treated soil the vanillin plot reduced growth in green weight from 100 for the check to 90, and in dry weight from 100 to 93. This apparent harmful effect of vanillin in the limed soil with acid phosphate is probably accidental and within experimental error, as in the other plots where lime was used no harmful effects were observed. With the amount of acid phosphate used increased acidity is out of the question, as there was an excess of lime applied and the plots were neutral throughout the season, as shown by chemical tests.

In the acid-phosphate plot the salicylic aldehyde reduced growth very little, in fact no difference was observable during the period of growth, but in green weight the aldehyde plot produced 5 percent less than the check, while in dry weight there was only a reduction of 2 percent. It is seen then that in the limed soil vanillin had practically no harmful effect. The harmfulness of salicylic aldehyde was greatly lessened, and with acid phosphate and lime together practically no harmful effects were observed.

EXAMINATION OF THE SOILS FOR ALDEHYDE.

Samples of soil were taken from each plot August 24, the day on which the crops were harvested, for the purpose of examining them in the laboratory to ascertain if the vanillin and salicylic aldehyde were still present in the soil.

An acidity test made of the various plots showed that each of the unlimed plots was acid and all of the limed plots were neutral or slightly alkaline.

Soil from each plot was examined for aldehydes by the method described in Bulletin 88, Bureau of Soils, and in Bulletins 108 and 164 of the U. S. Department of Agriculture. Twenty pounds of soil were used in the test. The method, in brief, consists of first making an alkaline extract of the soil. The extract is then acidified and filtered and then shaken out with ether. The ether extract is shaken with a concentrated aqueous solution of sodium bisulfite, which will remove aldehydes from the ether solution if present, by forming a water-soluble combination of sodium bisulfite and aldehyde. The bisulfite solution is separated from the ether, strongly acidified with sulfuric acid and air blown through to remove the sulfur dioxide liberated. This acidified solution in which the aldehyde is now liberated from its combination with the bisulfite is shaken with ether. If aldehydes are present they can be detected in the residue from the ether. This residue is purified by taking up in water, extracting with ether, filtering and evaporating. To portions of the residue are added certain reagents, which give color reactions with aldehydes. This will determine whether or not aldehydes are present but does not differentiate between the various aldehydes. In the case of soils treated with vanillin and salicylic aldehyde the only determination made was whether aldehyde material was still present or not.

Soil from the untreated plots, subjected to the above described process, was found to contain no aldehydes. The plot to which vanillin had been added, but no fertilizers, was found to contain aldehyde.

After making the color reactions the remaining portion of the residue was dissolved in water and used as a culture solution for the growth of wheat seedlings. Seedlings were grown in distilled water as a check. Growth was reduced 30 percent by the extracted substance, showing it to be very harmful to wheat plants.

No aldehyde was found in the soil from the plots treated with vanillin and sodium nitrate, or with vanillin and acid phosphate. The ether extract secured in the process of the isolation of aldehyde usually gives a residue of some kind. The residue secured from these two soils, when dissolved in distilled water, showed no harmful effects on wheat plants, so whatever this residue was it was not harmful to plants, as was that from the unfertilized aldehyde plot, which by the color reactions was shown to contain aldehydes.

Soil from the plots to which salicylic aldehyde, salicylic aldehyde and sodium nitrate, and salicylic aldehyde and acid phosphate were added was examined and each was found to contain aldehyde. In each case there was a good amount of residue from ether extract which gave the color reactions for aldehyde. In the plant test the residue from the salicylic-aldehyde plot reduced growth 25 percent; from the salicylic aldehyde and sodium nitrate plot, 7 percent; and from the salicylic aldehyde and phosphate plot, 11 percent. The material extracted from each of these soils was harmful; there was considerably more effect from the substance from the salicylic aldehyde unfertilized plot than from the other two.

No indications of the presence of aldehydes were found in any of the soils from the limed plots, which would tend to show that the added vanillin and salicylic aldehyde did not remain in the soil as such during the growing season. Lime might either have a direct chemical effect or stimulate oxidation and life processes in the soil, which would cause such substances as aldehydes to be oxidized or otherwise changed. The vanillin and salicylic aldehyde had very little effect on the crop in the limed plots, which is in harmony with the fact that they were not found to remain in the soil under these conditions.

It might also be pointed out that the sodium nitrate partly overcame the effects of vanillin and at the end of the growing season no vanillin was found in the soil, which would indicate that sodium nitrate fertilizer made conditions such that vanillin could not exist in this soil. Neither was vanillin found at the end of the experiment in the soil to which acid phosphate had been added, yet the vanillin had affected the growth, which may have occurred when the material was first added to the soil.

The salicylic aldehyde with and without fertilizers was found to remain in the unlimed soil throughout the growing season; however, the acid phosphate greatly lessened its effects on growth. These methods for the isolation of aldehydes are not quantitative and it may be that only a small part of the aldehyde remained in the soil, while most of it was changed or destroyed and did not long remain to influence plant growth.

As in the previous work, the experiment this year shows that added vanillin and salicylic aldehyde remain in the untreated Arlington soil throughout the growing season, yet they do not exist for a long period when the soil is limed or treated with certain fertilizers.

The Results Obtained in 1915.

The experiment at Arlington was continued in 1915. The same plots were used, each plot receiving the identical treatment given in 1914. Vanillin, salicylic aldehyde, and the fertilizers were used in the same quantities. The lime was added this year at the rate of only 1 ton per acre; in all other details the test was the same as in 1914. The New Era variety of cowpea was used.

The first application of aldehydes and fertilizers was made May 29, 1915, and the cowpea seed planted immediately afterwards. The second application was made June 21, when the plants were several inches high; and the third and last portion, July 15.

NOTES ON GROWTH.

The plots were showing differences as early as July 7. Notes taken on that date show that plants on the vanillin and salicylic-aldehyde plots of the no-fertilizer series were much smaller than the checks. The leaves of the plants on the vanillin plot again this year seemed affected; they were twisted and curled.

In the sodium-nitrate section the vanillin-plot plants were almost as large as the nitrate check, while the salicylic-aldehyde-plot plants were considerably smaller than the check.

In the phosphate section the vanillin-plot plants were considerably smaller than the check and the salicylic-aldehyde-plot plants were only slightly smaller. The substances at this stage of the growth showed somewhat the same effects as in 1914. That is, that the vanillin is not very harmful in soil fertilized with sodium nitrate and the salicylic aldehyde is less harmful with acid phosphate. Again the lime plots have made better growth than the unlimed and the effect of the aldehydes is only slight.

WEIGHTS OF GREEN AND CURED CROP.

The vines were beginning to mature August 27 and the crop was cut for hay on that date. Some of the peas were ripening but none were picked from the vines. The green and dry weights were taken of the vines and peas together. After the crop was cut and weighed they were spread upon the plot to cure. The dry weights were taken September 3. The results are given in Table 2.

TABLE 2.—*Effect of vanillin and salicylic aldehyde on cowpeas grown in the field on Susquehanna silty clay loam in 1915, and the action of fertilizers in modifying their effects (weights given in pounds per plot).*

Treatment.	Unlimed soil.				Limed soil.			
	Green weight.		Dry weight.		Green weight.		Dry weight.	
	Pounds.	Relative weight.	Pounds.	Relative weight.	Pounds.	Relative weight.	Pounds.	Relative weight.
No fertilizer section:								
Check *A*	32.0	100	14.0	100	46.0	100	21.0	100
" *B*	34.0		16.0		44.0		20.0	
Vanillin	26.0	79	11.5	77	47.0	104	21.0	102
Salicylic aldehyde	24.5	74	11.0	73	41.0	91	18.5	90
Sodium nitrate section:								
Check *A*	42.0	100	21.5	100	46.0	100	20.5	100
" *B*	39.5		18.5		44.5		19.0	
Vanillin	39.5	97	18.0	90	44.5	85	18.5	93
Salicylic aldehyde	34.5	85	16.0	80	45.0	100	18.5	93
Acid phosphate section:								
Check *A*	36.0	100	20.0	100	47.0	100	20.0	100
" *B*	33.5		18.5		44.0		17.0	
Vanillin	31.5	91	15.0	80	43.0	94	18.5	100
Salicylic aldehyde	32.5	93	17.0	88	44.5	98	17.0	92

The effects of the aldehydes in 1915 were very much like the results secured the previous year. In the unlimed soil the harmfulness of both vanillin and salicylic aldehyde were much more marked than in the limed soil.

In the no-fertilizer section of the unlimed soil vanillin reduced growth from 100 to 79 in green weight and from 100 to 77 in dry weight. In the sodium-nitrate plots vanillin reduced growth only 3 percent in green weight and 10 percent in dry weight, and in the acid-phosphate plots the growth was reduced in green weight from 100 to 91, a reduction of 9 percent, and from 100 to 80 in dry weight, a reduction of 20 percent. Again the harmfulness of vanillin was lessened by sodium nitrate.

Salicylic aldehyde reduced growth in the no-fertilizer section 26 percent in green weight and 27 percent in dry weight, while in the acid phosphate section growth was only reduced 7 percent of green

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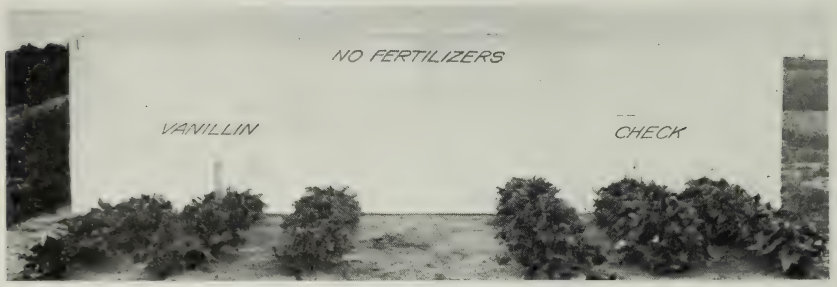

FIG. 1. Effect of vanillin on cowpeas in Arlington soil, without fertilizers (1915).

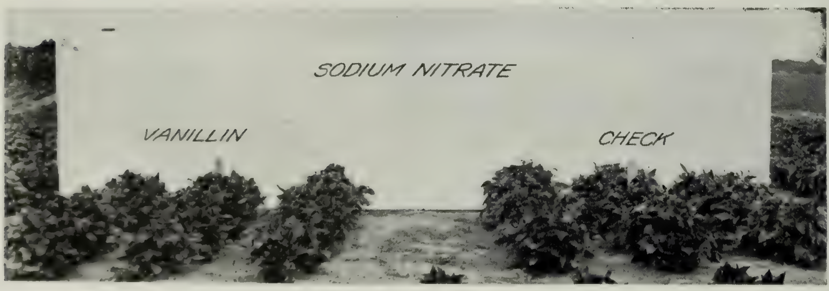

FIG. 2. Effect of vanillin on cowpeas in Arlington soil, with sodium nitrate (1915).

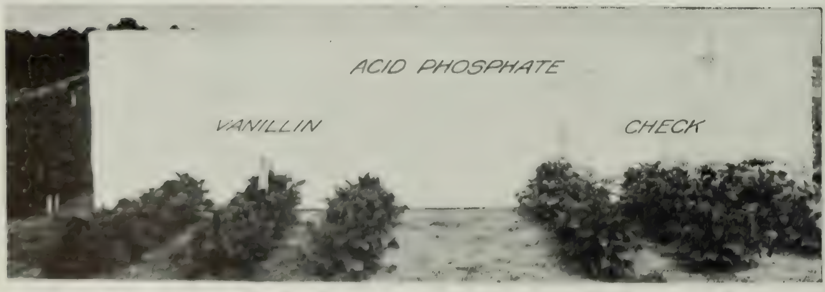

FIG. 3. Effect of vanillin on cowpeas in Arlington soil, with acid phosphate (1915).

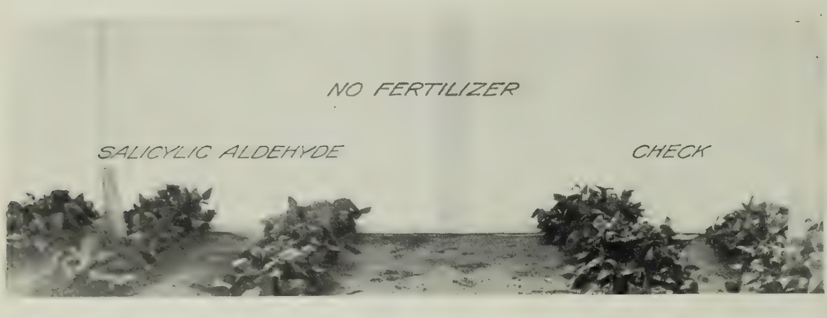

FIG. 1. Effect of salicylic aldehyde on cowpeas in Arlington soil, without fertilizers (1915).

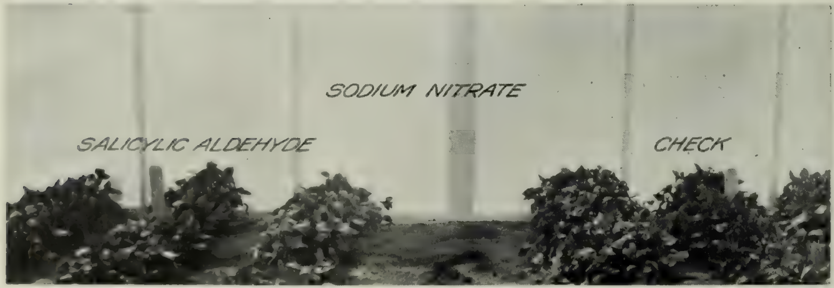

FIG. 2. Effect of salicylic aldehyde on cowpeas in Arlington soil, with sodium nitrate (1915).

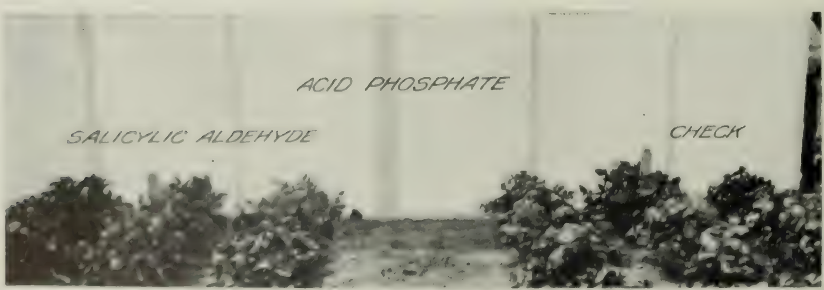

FIG. 3. Effect of salicylic aldehyde on cowpeas in Arlington soil, with acid phosphate (1915).

weight and 12 percent of dry weight. These results are also similar to those secured in 1914. As stated before, the aldehydes had very little effect in the limed soil.

The photographs of the growing cowpeas, shown in Plates XII and XIII, show these results strikingly.

EXAMINATION OF THE SOIL FOR ALDEHYDES.

After the crop was harvested on August 27 the soil from each plot was examined for the presence of aldehydes. The method already described was used.

Of the unlimed plots to which vanillin had been added aldehydes were found to be present in both the unfertilized vanillin plot and in the acid-phosphate vanillin plot. The material isolated from both of these soils was harmful to wheat seedlings in distilled water. No aldehyde was found in the vanillin plot which had been fertilized with sodium nitrate.

Each of the unlimed plots to which salicylic aldehyde had been applied was found to contain aldehyde at this time, and this isolated aldehyde material proved to be harmful to wheat plants in each case.

No aldehydes were found in any of the plots on the limed soil, showing the complete disappearance of these substances under the influence of lime.

In both 1914 and 1915 vanillin and salicylic aldehyde added to the unlimed soil remained as such to affect crop growth throughout the growing season. In both years the aldehydes had only a slight effect on crop growth in the limed soil, and now, when the soil is examined at harvesting time, none is found to have persisted in the soil throughout the season.

In both 1914 and 1915 vanillin added to the soil fertilized with sodium nitrate was not found to be present several months after its application. It appears that sodium nitrate acts in the soil in such a way as to destroy vanillin or change it to more highly oxidized compounds that are not harmful to plant growth.

The behavior of these compounds as to their effect on crop growth and as to their permanency in another type of soil which is entirely different in character, and in a different climate, will be interesting to compare with the experiments at Arlington. It has been shown that even on the Arlington soil under different fertilizing practices the substances behave differently. The experiments on the Hagerstown loam were conducted to study these effects on a more fertile soil.

Before presenting the results obtained on this more fertile soil, having a higher oxidative capacity, it will be well to present some experiments and observations made as to the influence of this oxidative factor as determined on the differently treated and differently fertilized plots on the Arlington soil. The experiments seem to indicate a certain relationship between increased oxidation on the one hand and decreased toxicity and destruction of aldehydes on the other.

EFFECT OF VANILLIN AND SALICYLIC ALDEHYDE ON THE OXIDATION OF THE SOIL.

Oxidation by plants is a factor which has considerable bearing on soil fertility. By oxidation the plant may change the organic matter in the medium in which it is growing. The oxidizing power of plant roots grown in extracts of productive soils is greater than that of plant roots grown in extracts of unproductive soils. The presence of vanillin and cumarin in a culture solution greatly checked oxidation by the plant roots.[16] Soils themselves have oxidizing power, and the degree of oxidative power which a soil possesses varies with the soil. As a rule soils that are known to be productive have strong oxidative power and poor soils have little or no oxidative power. Whatever decreases oxidation in soils tends also to bring about conditions which decrease growth, and the factors which favor oxidation are the factors which favor soil productivity.[17]

The oxidative power of the silty clay loam at Arlington is relatively poor as compared to other agricultural soils, and the oxidation of the Hagerstown loam at State College, Pa., on which the aldehyde experiments were also made, is very good; in fact the oxidation in this soil was found to be among the best of a long list of soils tested.[18] Oxidation studies were made of the soils on the Arlington plots to determine the effect of added vanillin and salicylic aldehyde.

For this purpose samples were taken July 16, before the last application of aldehydes was made; July 23, seven days after the last application; and on November 19, about two and one half months after the crops were harvested and four months after the last application of aldehydes. The method used in testing the oxidative power of these soils is the same as that described in Bulletin 73 of the Bureau of Soils. The method, in brief, consists of shaking 20 grams of soil in a water solution of aloin, allowing to settle and adding 50 cc. of alcohol to flocculate the soil and to extract the oxidized aloin. The solution is then centrifuged, the supernatant liquid poured off and the depth of color in the solutions compared by means of a colorimeter.

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[16] Schreiner, O., and Reed, H. S. The Rôle of Oxidation in Soil Fertility. U. S. Dept. Agr., Bur. Soils Bul. 56. 1909.

[17] Schreiner, O., Sullivan, M. X., and Reed, F. R. Studies in Soil Oxidation. U. S. Dept. Agr., Bur. Soils Bul. 73. 1910.

[18] U. S. Dept. Agr., Bur. Soils Bul. 73.

The oxidation of the untreated plot and the effect of sodium nitrate, acid phosphate, and lime on the oxidation of the soil will first be considered. The relative oxidation of the fertilized plots as compared with the untreated soil is given in Table 3.

TABLE 3.—*Effect of fertilizers and lime on soil oxidation in a Susquehanna silty clay loam.*

Treatment.	Relative oxidation.			Relative average oxidation.
	July 16.	July 23.	Nov. 19.	
Soil untreated	100	100	100	100
Soil + sodium nitrate	131	127	121	126
Soil + acid phosphate	109	95	89	97
Soil + lime	138	134	100	124
Soil + lime + sodium nitrate	147	144	121	137
Soil + lime + acid phosphate	131	121	81	111

The oxidative power of the samples taken July 16 is given in the second column of the table; in the third column is given the oxidation of the soil July 23; and in the fourth column the oxidation on November 19. In the last column the averages of the three periods are given.

It is seen from the table that sodium nitrate has greatly increased the oxidation of the soil. At each period the oxidation was greater in the sodium-nitrate plot than in the untreated plot. The average for the three periods was 126 for the sodium nitrate against 100 for the check plot.

The acid phosphate increased oxidation only once, and that was in the first period. At the other two periods the oxidation was less than that of the untreated soil. An average of the three periods gave an oxidation of 97 for the acid-phosphate plot against 100 for the check.

The limed soil also increased oxidation; in the first two periods the oxidation was greater than that of the check plot and in the third period the check and the limed plots were the same. An average of the three periods gave 124 for the limed soil against 100 for the check.

It is also seen that lime plus sodium nitrate increased oxidation greater than any other treatment. The average for the three periods was 137 against 100 for the check.

Lime plus acid phosphate caused less oxidation than lime alone, yet there was on the whole more oxidation than in the untreated soil. The oxidation of the lime and phosphate plot was less in each period than in the limed plot. Inasmuch as phosphate decreased oxidation when used alone and again when used with lime, it appears that acid phosphate hinders the oxidative power of this soil.

In previous work in this laboratory it was shown that fertilizers influenced the oxidation in Arlington soil, sodium nitrate greatly increased oxidation, and phosphate only slightly. With some other soils this was also found to be true; however, in numerous experiments made on the effect of fertilizers on the oxidative power of soils the results showed that fertilizers sometimes increased oxidation and sometimes decreased it, and that the effects of fertilizers are different in different soils.[19]

The oxidizing power of plant roots is also influenced by calcium carbonate and fertilizer salts. Calcium carbonate increases the oxidative power of plants growing in distilled water and in soil extracts. Sodium nitrate also has this power. Calcium acid phosphate, however, depressed the oxidizing power of the plants in soil solutions.[20] Thus the results secured on the Arlington plots are in accord with those secured in the earlier work on the oxidation of soils and on the oxidizing power of plants in soil solutions.

Interesting results were obtained with the effect of vanillin and salicylic aldehyde on the oxidizing power of the Arlington soil. The relative oxidation determinations of these plots are given in Table 4.

TABLE 4.—*Effect of vanillin and salicylic aldehyde on soil oxidation in a Susquehanna silty clay loam.*

Treatment.	Unlimed soil.				Limed soil.			
	July 16.	July 23.	Nov. 19.	Relative average oxidation	July 16.	July 23.	Nov. 19.	Relative average oxidation.
Soil unfertilized	100	100	100	100	100	100	100	100
Soil + vanillin	104	96	94	98	85	121	89	98
Soil + salicylic aldehyde	89	85	81	85	95	94	89	93
Soil + sodium nitrate	100	100	100	100	100	100	100	100
Soil + sodium nitrate + vanillin	86	72	93	84	89	100	77	89
Soil + sodium nitrate + salicylic aldehyde	95	82	93	90	100	89	87	92
Soil + acid phosphate	100	100	100	100	100	100	100	100
Soil + acid phosphate + vanillin	82	80	100	87	100	110	90	100
Soil + acid phosphate + salicylic aldehyde	100	109	112	107	105	119	157	127

In this table the soil without vanillin or salicylic aldehyde in each case is taken as 100. That is, the plots unfertilized are compared among themselves, and each group fertilized is similarly compared with its own treated check as 100.

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[19] U. S. Dept. Agr., Bur. Soils Bul. 73.

[20] U. S. Dept. Agr., Bur. Soils Bul. 56. 1909.

The first half of the table gives the result on the unlimed soil and the second half the result on the limed soil. As in the preceding table, the oxidation for each of the three periods is given and an average of the three.

In the unfertilized soil vanillin reduced the oxidation slightly. In the first period there was a slight increase and in the other two periods a slight decrease. An average of the three periods showed a decrease in oxidation in the vanillin plot to 98 as compared to 100 for the check. The salicylic aldehyde decreased oxidation very much in each period. An average of the three periods gave an oxidation of 85 for the treated plot against 100 for the check.

In the soil treated with sodium nitrate the oxidative power of the vanillin plot was much less in each period than in the sodium nitrate check. The salicylic aldehyde was also less than the check, but the oxidation was not lessened as much as in the vanillin-treated soil. It should be remembered, however, that the sodium-nitrate check plot had itself increased greatly in oxidation over the untreated soil, which means that the soil in each of these plots has very good oxidation, and much better than in the corresponding plots in the no-fertilizer section. Yet the vanillin and salicylic aldehyde have their influence in checking oxidation even with this fertilization.

Considering the section treated with acid phosphate, vanillin has lessened oxidation, yet the salicylic aldehyde has slightly increased this function over the acid-phosphate check.

In the limed soil the compounds have also decreased the oxidizing power of the soil, except plots to which acid phosphate was added. Where lime and phosphate were used together the oxidation in the vanillin plot was the same as in its check, and in the salicylic-aldehyde plot the oxidation was increased from 100 for the check to 127. It should also be borne in mind that the limed check plots had a greater oxidizing power than the unlimed, unfertilized soil, which means that each of the plots on the limed soil had a greater oxidizing power than the corresponding plot on the unlimed soil. However, the oxidizing power of the soil was decreased by applying vanillin and salicylic aldehyde, except where acid phosphate was used. This action of acid phosphate in combating the effects of salicylic aldehyde, and of vanillin to some extent, is rather surprising. In the former work and also in the plots in this experiment, where no aldehydes were used, the acid phosphate did not have an appreciable influence in stimulating oxidation processes in the soil. However, this increased oxidation is in harmony with the increased crop yields and with the effect of phosphate in lessening the harmfulness of salicylic aldehyde to plant growth.

EFFECT OF ALDEHYDES ON HAGERSTOWN LOAM.

The test of the two aldehydes was made on the Hagerstown loam[21] on the Pennsylvania Experiment Station Farm at State College, Pa., in 1914 and in 1915. The plan of the experiment is given in figure 10 and is the same as was used at Arlington. The size of the plots differed, however. The plots at State College were 10 feet square, one four-hundred-and-thirty-fifth of an acre. The Early Buff variety of cowpeas, the same as used at Arlington, was grown in 1914.

The field in which the experiment was made is in a good state of fertility. In 1913 the field produced a good crop of corn. It was manured with stable manure at the rate of 12 tons per acre. The soil produces good crops of wheat, grass, clover, corn, and soy beans.

The surface soil of the experimental plots consists of about 10 inches of brown to yellowish brown loam. It is underlain from 10 to 20 inches by a yellowish brown heavy silt loam which grades to a heavy red clay within 3 feet. The soil is loose and friable and is very easily worked.. The drainage is excellent. The Hagerstown loam of this area is formed from disintegrated dolomite limestone and is recognized as among the best soils of the country, and by far the most productive soil of Center County.

The soil in the experimental plots contains considerable organic matter, fully as much as the soils of this type in this area. A laboratory test showed the soil to be only slightly acid. The ground selected for the plots is 72 feet by 44 feet, the plan of which is given in figure 10. Each pair of plots is separated by a 2-foot path. There is a very slight but uniform slope from the north plots (the no-fertilizer group). The soil of this piece of ground is fairly uniform. The vanillin plot and check *B* plot of the acid phosphate section on the limed soil are the lowest plots of the entire series; the slope is towards them and they are somewhat darker and richer in organic matter.

THE RESULTS OBTAINED IN 1914.

The general details of the experiment as to the application of aldehydes, fertilizers, etc., were the same as those described in the Arlington test. The vanillin was applied at the rate of 300 pounds per acre and salicylic aldehyde at the rate of 150 pounds per acre. One third of the total application was applied before the seed was planted May 26, 1914; one third on July 1, and the remaining one third July 29. Sodium nitrate was used at the rate of 180 pounds per acre and acid phosphate at the rate of 360 pounds per acre.

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[21] For a detailed description of the Hagerstown loam soil of this area see the report of the soil survey of Center County, Pa., by C. N. Mooney, C. F. Shaw, T. A. Kolbe, H. H. Bennett, and R. T. Allen. Field Operations, Bureau of Soils, 1908.

The cowpeas were planted May 27. Unfortunately, the season was very dry during May and June and as a result of this a very poor stand was secured, so on June 24 the spaces on which peas had failed to germinate were replanted.

NOTES ON GROWTH.

Throughout the period of the experiment the plots showed a ragged appearance, as the replanted peas were much smaller than the first planting and were much later in maturing. The crop was harvested September 19. At this time most of the peas from the first planting were fully matured and some leaves had dropped from a number of the vines, while plants from the second planting were still green. This fact vitiates the results to a certain extent, and makes them inconclusive, so that the results will be only briefly stated.

On the unfertilized soil vanillin and salicylic aldehyde had very little effect; there was no striking difference in appearance of the plants as they grew upon the plots. The weights of the vanillin plot showed a reduction of 6 percent in dry weight of hay. The yield of cured hay on the salicylic-aldehyde plot was practically the same as on the check plots. On the soil fertilized with sodium nitrate both aldehydes reduced growth only slightly, approximately 5 percent. On the soil fertilized with acid phosphate the growth on the vanillin plot was fully as good as the checks and the salicylic aldehyde reduced growth only slightly. In the limed soil there was a depression in growth by vanillin and salicylic aldehyde in the no-fertilizer section. However, the growth in the aldehyde plots on the sodium-nitrate section and acid-phosphate section was fully as good as in the respective checks.

The most that can be said of these results is that the vanillin and salicylic aldehyde have very little effect in this soil. It is not possible to draw any definite conclusion as to the influence of fertilizers on the physiological effects of the organic compounds from these data. As the season was so unfavorable in 1914 and the poor stand from the first planting made the experiment so uncertain, it was repeated on the same plots in 1915 under more favorable conditions. The results for the second experiment are given in the following pages.

EXAMINATION OF THE SOIL FOR ALDEHYDES.

The soils were examined to determine if the added vanillin and salicylic aldehyde were still present in the soil at the end of the growing period. Twenty pounds of soil were taken from each plot on October 9 and subjected to the process for the isolation of aldehydes already described in this paper.

The test showed the presence of aldehydes in only one plot. This was the plot to which salicylic aldehyde had been added on the sodium-nitrate section of the unlimed soils. The extracted material from this soil gave the color reactions for aldehydes. This material when dissolved in distilled water was harmful to wheat seedlings, reducing growth about 30 percent. Notes taken in September show that the growth on this plot was the poorest in the series, yet at the end of the season this was not especially noticeable. No reason can be assigned why the aldehyde should persist in this particular plot, while in every other case it was not found to be present.

It is rather significant that in the Hagerstown soil, which is a strong productive soil with strong oxidizing power, the aldehydes when added did not stay as such but were destroyed or changed, while in the Arlington soil, which is an unproductive one, with low oxidizing power, the added aldehydes persisted for months and remained as such throughout the growing season to have their effect on the crop.

The Results Obtained in 1915.

The experiment was conducted the second year on the identical plots used in the first test.

The ground was prepared late in the spring and on June 10 the cowpeas were planted. The New Era, an early maturing variety, was used. Previous to planting, the first portion of the vanillin, salicylic aldehyde, and fertilizers was applied to the respective plots. The soil limed in 1914 was found to be slightly alkaline at this time, so no more lime was added. The unlimed section showed a slight acid reaction.

The peas germinated well and a uniform stand was secured. On June 28 the plants were 2 to 3 inches high. The plants on the vanillin and salicylic aldehyde plots of the unfertilized section appeared at this time to be slightly behind the plants on the other plots. On this date the second portion of aldehydes and fertilizers was applied.

NOTES ON GROWTH.

On July 19 the plots were showing some differences in growth. On the unlimed soil the two checks in the no-fertilizer section have made

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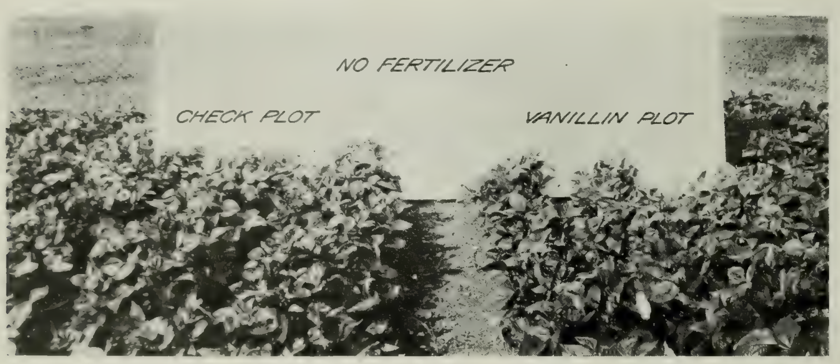

FIG. 1. Effect of vanillin on cowpeas in Hagerstown loam, without fertilizer (1915).

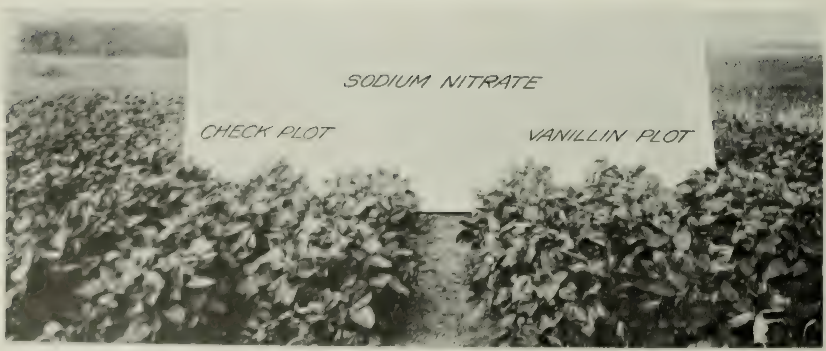

FIG. 2. Effect of vanillin on cowpeas in Hagerstown loam, with sodium nitrate (1915).

about equal growth. The plants on the vanillin plot have made less growth than the checks. They appear about 20 percent smaller. They are not as tall nor have they broadened out as much as the checks. On the salicylic-aldehyde plot the growth is much better than the vanillin plot, but it is not as good as the check plots. There seems to be a difference of about 10 percent in growth.

On the fertilized soil the growth on the differently treated plots is more uniform; the plants on the vanillin and salicylic-aldehyde plots are somewhat smaller than the checks. The growth on the whole is good on all the plots; the plants are strong, healthy and thrifty.

The third and final application of materials was made July 19. On September 9 photographs were taken of some of the plots and these are shown in Plate XIV, figures 1 and 2. At this time the vanillin and salicylic-aldehyde plots of the no-fertilizer section on the unlimed soil were smaller than their checks. This was especially true of the vanillin plot. On the sodium nitrate section the growth on the vanillin plot was almost as good as the respective check.

WEIGHT OF GREEN AND CURED CROP.

The crop was cut and weighed September 13. The plants had made their full growth but were still green and full of blooms. The weight of the entire plant was taken; no attempt was made to pick the peas as they were immature. After the green weight was taken the vines were spread upon the plots and allowed to become dry. The weight of the cured hay was taken September 15 and the yields are given, together with the green weights, in Table 5.

As seen in the table, the two check plots in the no-fertilizer section of the unlimed soil produced approximately the same yield. The vanillin reduced the green weight yield from 100 as an average of the two checks to 84, a reduction of 16 percent. In dry weight there was also a 16 percent decrease. The salicylic aldehyde reduced growth in green weight from 100 to 88, a reduction of 12 percent, and in dry weight from 100 to 87, or 13 percent.

On the sodium-nitrate soil the aldehydes had less harmful effects. The vanillin reduced the yield only 3 percent in green weight, and in dry weight there was an increase of 2 percent. As the crop grew it was apparent that the growth on the vanillin plot was as good as the checks; the foliage and the number of runners were about the same on both plots. The growth on the salicylic-aldehyde plot was not altogether as good as the checks. The foliage was not so dense and there were fewer runners. In the table it is seen the green weight was reduced from 100 to 90, a reduction of 10 percent, and in dry weight there was a reduction of 9 percent.

In the acid-phosphate section the growth on the vanillin plot was somewhat smaller than on the checks. Considering the green weight, growth was reduced from 100 to 91, a reduction of 9 percent, and in dry weight a reduction of 13 percent. On the salicylic-aldehyde plot the growth was as good as on the checks. This was apparent before the crop was cut. The density of the foliage and the number of runners were about the same on both plots.

TABLE 5.—*Effect of vanillin and salicylic aldehyde on the growth of cowpeas on Hagerstown loam at State College, Pa., and the effect of fertilizers and lime (results given in pounds per plot).*

Treatment.	Unlimed soil.				Limed soil.			
	Green weight.		Dry weight.		Green weight.		Dry weight.	
	Pounds.	Relative weight.	Pounds.	Relative weight.	Pounds.	Relative weight.	Pounds.	Relative weight.
No fertilizer section:								
Check *A*	59.00	100	21.75	100	62.50	100	23.50	100
Check *B*	60.25		22.50		61.00		23.50	
Vanillin	50.00	84	18.50	84	56.00	91	20.00	85
Salicylic aldehyde	53.50	88	19.25	87	57.00	92	21.75	93
Sodium nitrate section:								
Check *A*	63.00	100	23.25	100	58.00	100	21.00	100
Check *B*	60.00		22.75		55.50		21.25	
Vanillin	59.50	97	23.50	102	55.00	97	21.50	102
Salicylic aldehyde	55.50	90	21.00	91	55.00	97	22.50	106
Acid phosphate section:								
Check *A*	59.00	100	22.00	100	62.00	100	24.25	100
Check *B*	61.00		24.50		67.00		28.25	
Vanillin	54.50	91	20.25	87	67.00	104	26.75	[a]102
Salicylic aldehyde	61.50	103	23.25	100	61.00	95	23.25	[a] 89

[a] See discussion in the text.

On the unfertilized section of the limed soil neither vanillin nor salicylic aldehyde had very much effect. In green weight there was a reduction of 9 percent in the vanillin plot and 8 percent in the salicylic-aldehyde plot. The reduction in dry weight was 15 percent for vanillin and 7 percent for salicylic aldehyde. On the limed soil fertilized with sodium nitrate or acid phosphate neither aldehyde had any appreciable harmful effect.

A close examination of the table shows that the yields of the duplicate check plots are very close together, except in the acid-phosphate section of the limed soil. Check *A* produced only 62 pounds green matter and 24¼ pounds dry hay, while check *B* produced 67 pounds green matter and 28¼ pounds dry hay. This was apparent during the growing season. On close examination of the soil of the two plots it was found that the surface soil in check *B* was several inches deeper and had more organic matter. This was also true of the adjoining vanillin plot. The lay of the ground is such as to make it possible for check *B* plot and the vanillin plot to get the drainage from several of the surrounding plots. Under the circumstances, in this section it would be better to compare the vanillin plot with check *B,* and the salicylic-aldehyde plot with check *A*. By making this comparison it is seen the yield in the vanillin plot is as good as in check *B,* and the yield in the salicylic-aldehyde plot is almost the same as in check *A*.

In the unlimed soil with no fertilizers both the vanillin and salicylic aldehyde had a depressing effect on crop growth, but this was not very marked. When the soil was fertilized with sodium nitrate the harmfulness of both compounds was lessened. This was especially so with vanillin, where practically no depression in growth was observed. Acid phosphate also ameliorated the effects of both compounds. In this case salicylic aldehyde had no depressing effects.

On limed soil the effects were noticeable but their harmfulness was not as much as on the unlimed soil. There were no effects from the aldehydes on the limed soil fertilized with sodium nitrate or acid phosphate.

EXAMINATION OF THE SOILS FOR ALDEHYDES.

Samples of soil were taken September 15, after the crop was harvested, and examined to determine if the soil still contained the aldehydes. The methods previously described were used.

No aldehydes could be isolated from any of the plots. Such harmful effects as were observed were probably due to the influence of the added materials at the time and shortly after its application. There were three applications, the first on June 10, when the seeds were planted, and the last on July 19, when the plants had made considerable growth. If the aldehydes had remained in the soil as such throughout the growing season the crops would undoubtedly have shown their effects to a much greater extent.

The nature of this soil seems to be such that organic compounds of the kind added cannot exist for any length of time, nor could harmful compounds of this nature be formed or remain in this soil. It has been pointed out that the Hagerstown soil has a strong oxidizing power and is otherwise a fertile productive soil. These added aldehydes are undoubtedly acted on in the soil and destroyed or changed to other compounds that are not harmful.

The contrast between the action of aldehydes in the Arlington soil and in the Hagerstown loam is interesting and demonstrates that such materials can exist in one soil and have their effect on growth, while in another soil they are destroyed by oxidation or other life processes of the soil and do not remain for a sufficient length of time to have an appreciable influence.

Summary.

In a two years' field test vanillin and salicylic aldehyde proved harmful to cowpeas in a silty clay loam at the Arlington Farm, Va. The action of both vanillin and salicylic aldehyde was modified by fertilizers. The harmful effect of vanillin was lessened by sodium nitrate fertilizer and the effect of salicylic aldehyde was lessened by acid phosphate. The effects of both vanillin and salicylic aldehyde were overcome by liming the soil. These field results are in harmony with the effect of fertilizer salts on the behavior of these compounds in water culture solution.

Vanillin and salicylic aldehyde were found in this Arlington soil several months after they were applied and after the end of the crop season. On the plots fertilized with sodium nitrate the vanillin had been changed or destroyed and did not remain as such to have its effect on the crop. Neither vanillin nor salicylic aldehyde was found to remain in the limed soil.

The oxidizing power of the Arlington soil was checked by both vanillin and salicylic aldehyde and this lessened oxidation was increased by fertilizers and by lime.

Vanillin and salicylic aldehyde had only a slight harmful effect on a productive Hagerstown loam at the Pennsylvania Experiment Station, State College, Pa. Again the harmfulness of vanillin was ameliorated by sodium nitrate and that of salicylic aldehyde by acid phosphate, and on limed soil the aldehyde compounds had no, or only slight, harmful effects.

When these State College soils were examined at the end of the growing season to determine if the added aldehydes remained in the soil, none was found in any of the plots, which would seem to show that organic substances of this nature do not persist in this soil and consequently could have little or no effect on crop growth. This experiment demonstrates that such organic substances as aldehydes can exist in one soil and have their effect on growth, while in another soil they are destroyed by oxidation or other life processes of the soil and do not remain to have an influence on soil productivity.

THE FLOWERING HABITS OF TIMOTHY.[1]

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Introduction.

During the summer of 1914, a critical study was made of the blooming of timothy. Observations were also made during the blooming period in 1912, 1913, and 1915.[2] Especial attention was given to determining when timothy flowers begin to bloom, over how long a period the process continues, how and at what time of day the flowers open, the conditions under which they open most readily, the color of various parts of the flower and the general color effect of meadows, and other phases of the blooming process.

Description of the Blooming Process.

The first indication that a timothy flower has commenced to bloom appears when the glumes begin to open slightly and the extreme tips of the anthers become visible. After the anthers have emerged so that the bases are out as far as the tips of the glumes, the filaments continue to extend directly outward until they have reached full length. Until they begin to wilt, the filaments hold the anthers at about a right angle to the main axis of the spike. The average distance from the tips of the glumes to the tips of the anthers, when the filaments are fully extended, is slightly more than a fifth of an inch. The average length of the anther is slightly over a twentieth of an inch.

At about the time when the filaments have elongated so that the bases of the anthers are as far out as the tips of the glumes, and frequently before they have emerged quite so far, the tips of the stigmas become visible. As they gradually elongate, they also spread laterally and become somewhat featherlike in appearance. They ordinarily attain their full development at about the time the filaments have reached full length. As a rule, the tips of the stigmas, after the filaments are fully extended, do not extend as far as the base of the anthers.

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[1] Received for publication April 25, 1916.

[2] The observations on which this report is based were made on the Timothy-Breeding Station at New London, Ohio, which is conducted cooperatively by the U. S. Department of Agriculture and the Ohio Agricultural Experiment Station.

The time that elapses from the beginning of the blooming process until the filaments and stigmas are fully extended varies. The process takes more time, as a rule, in the early morning hours than after daybreak; it progresses more rapidly when the weather is warm than when it is cool. The time required for flowers to bloom has been observed to vary from less than an hour to about two and one half hours.

In all instances where timothy flowers have been observed while blooming, the anther sacs have remained closed until after both the filaments and stigmas have become fully extended. There is, therefore, an interval after the stigmas are exposed before any pollen from the anthers of the same flower is set free. The length of time that elapses before the anthers begin to open depends largely upon the atmospheric conditions. If there is a heavy dewfall, keeping them moist, all anther sacs of flowers that bloom in the early morning hours may remain closed for several hours, until the sun rises and the moisture from the dew begins to disappear. When there is but little dewfall or when the flowers bloom at about sunrise, the anther sacs usually begin to dehisce soon after the filaments and stigmas have grown to full length.

When the anther sacs dehisce, each half gradually opens longitudinally on the outer side, from the tip to the base. After the anther sacs have partially dehisced, any slight movement of the culm will set free large quantities of pollen, which may be seen floating away from the spike in a light yellow cloud. A miniature cloud of pollen has been observed to become released suddenly from an anther of a timothy flower in bloom, while the culm and spike remained quiet; apparently this was the result of some movement of the anther caused by the process of dehiscing.

Within an hour or two after sunrise, practically all of the anthers have dehisced and a large part of the pollen has become dislodged. By this time the filaments have become more or less wilted, allowing the empty anther sacs to fall down gradually on the spike. If the air is quiet, the empty anther sacs may remain on the spike for a day or more. If it is windy, however, they may be practically all removed within a few hours. The stigma remains attached to the flower and gradually dries and shrivels after the blooming process is completed.

When a timothy flower blooms, the glumes open at a small angle, little or no greater than is necessary to allow the three anthers to emerge simultaneously. The glumes close soon after the anthers are exserted.

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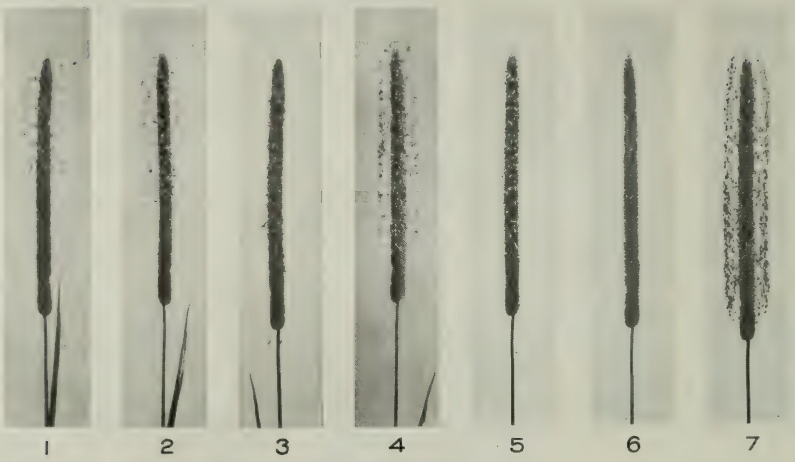

FIG. 1. Photographs of a spike of timothy (*Phleum pratense*) on successive mornings during the first seven days of the blooming period. Atmospheric conditions at 8 a.m. of each day and minimum temperatures during the preceding 24 hours were as follows: (1) June 25, clear, 69° F.; (2) June 26, light rainfall, 68° F.; (3) June 27, raining, 65° F.; (4) June 28, clear, 66° F.; (5) June 29, clear, 54° F.; (6) June 30, clear, 49° F.; (7) July 1, cloudy, 60° F.

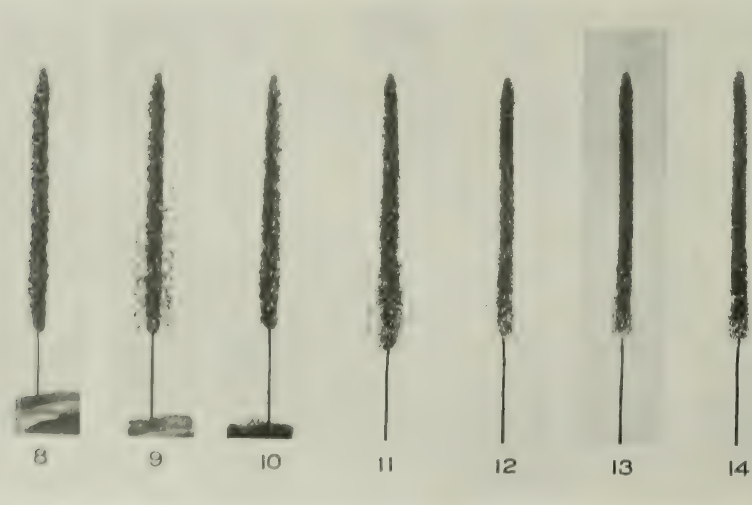

FIG. 2. Photographs of the same timothy spike shown in figure 1, on the seven succeeding days. Atmospheric and temperatures conditions were as follows: (8) July 2, raining, 60° F.; (9) July 3, clear, 53° F.; (10) July 4, clear, [illegible]° F.; (11) July 5, clear, 57° F.; (12) July 6, 56° F., (13) July 7, clear, [illegible]° F.; (14) July 8, clear, 56° F.

Progress of Blooming on the Spike.[3]

The flowers which bloom first on a timothy spike are some of those growing near the tip. On successive mornings flowers lower down on the spike bloom. The portions of the spike where the flowers are in bloom on different days overlap. It is usually several days and may be a week after the first flowers have bloomed before flowers at the extreme base bloom. Likewise, flowers at the base may bloom for several days after all flowers near the tip have passed out of bloom. Except as the process is affected by unfavorable weather conditions, the number of flowers that bloom each day gradually increases until flowers are in bloom through nearly the entire length of the spike, then gradually decreases until only a few flowers at the base are in bloom. The progress of blooming on a single spike from the time when the first flowers appeared until the last ones bloomed is illustrated in Plate XV.

Period During which Timothy Blooms.

At New London, Ohio, in the summers of 1912 and 1913, observations were made, at intervals of 3 or 4 days during the entire blooming period, of the number of flowers in bloom in broadcast plots of timothy grown from commercial seed. Similar observations were also made daily, in timothy plots and in meadows in the vicinity of New London, in 1914 and in 1915. The following extracts from the notes taken show the first and last date on which flowers were observed in bloom each season, and indicate fairly well over what period the blooming process extends:

1912.	June 17.	Flowers opening on many of the timothy spikes.
	July 11.	Flowers opening on a few scattered spikes.
1913.	June 23.	About 10 percent of the spikes with some open flowers.
	July 14.	Some flowers blooming on a few late plants.
1914.	June 16.	A few scattered plants with flowers in bloom.
	July 15.	Only a few flowers on late plants in bloom.
1915.	June 21.	A few early plants with flowers in bloom.
	July 19.	A very few late plants with flowers in bloom.

The above records show that the date when timothy flowers begin to bloom varies slightly in different seasons. The earliest flowers bloom about June 16 to 20 and the latest ones ordinarily about July 12 to 15, so that about 24 to 28 days elapse from the beginning to the end of the blooming season.

The dates given in the preceding paragraph are for plants growing in ordinary timothy meadows. On plants growing in cultivated rows flowers often continue blooming somewhat later in the season. Timothy spikes with flowers in bloom frequently have been found growing in row plots and also in meadows during the autumn.

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[3] A description of the blooming of timothy has been published by C. F. Clark, in The Plant World, 14: 131–135. June, 1911.

During the first few days and also during the latter part of the blooming period, the number of flowers in bloom is relatively small. The periods during which the number of flowers in bloom was large enough to make them appear conspicuous in the field in each of the four seasons in which observations were recorded were as follows: June 24 to July 3, 1912; June 26 to July 5, 1913; June 24 to July 3, 1914; and June 25 to July 10, 1915. These dates show that the time during which flowers bloom in large numbers in timothy fields in northern Ohio is ordinarily about 10 days, extending from June 24 or 26 to July 3 to 5. In 1915 the flowers continued to bloom in large numbers until July 10. The exceptionally large amount of rainfall in 1915 apparently caused the period of bloom to be prolonged.

The time at which the flowers bloom on the different plants in a timothy meadow varies considerably. In 1913 observations were made daily on eight plants growing in cultivated rows. These plants had been selected and transplanted from fields of ordinary timothy. On two of the eight plants a large number of flowers were in bloom on June 25, when the first record was taken; flowers on one or two spikes on each of three other plants were also in bloom on June 25. The first flowers bloomed on two other plants on July 2, while on the eighth plant no flowers bloomed until July 9. This variation in the time of blooming of flowers on different plants causes the blooming period for a timothy meadow to extend over a somewhat longer time than would otherwise be the case.

The flowers on the different spikes of a single timothy plant do not begin to bloom simultaneously, but come into bloom on different days, in approximately the same order in which the spikes emerge from the sheath of the upper leaf. All the flowers on the earliest spikes on a plant are frequently past bloom before the flowers on some of the later spikes on the same plant have begun to bloom.

In 1913 and 1914 records were made of the duration of the blooming period of the flowers on 18 spikes, on timothy plants growing in cultivated rows. The time during which flowers continued to bloom on each spike varied from 6 to 16 days.[4]

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[4] The time during which flowers bloomed on 25 spikes on 5 plants observed by Clark at Cornell University, as recorded in the paper previously cited, varied from 6 to 10 days.

The dates when plants in a timothy meadow begin and cease to bloom may be affected by the time of seeding the meadow. Flowers bloom somewhat later on plants grown from seed sown the preceding autumn than on plants in older meadows. On July 7, 1914, when flowers were in bloom on only a few of the small late spikes in older timothy plots and meadows, a very large number of flowers bloomed in a plot seeded on October 4, 1913.

Time of Day When Timothy Flowers Bloom.

In the summer of 1914, plots of timothy were observed during the blooming season in order to determine at what time of the day the flowers bloom. The observations extended over a period of 15 days, from June 22 to July 7, inclusive. From June 22 to July 3, observations were made in a plot of ordinary timothy seeded in 1911. From July 3 to July 7, observations were continued in a plot of timothy seeded in the preceding autumn, where the flowers bloomed in large numbers several days later than in the plot seeded in 1911. During the period over which this study extended, the plants were observed from 8 p.m. until 8 a.m. at 2-hour intervals, with occasional exceptions. Frequent observations were made, at less regular intervals, from 8 a.m. to 8 p.m. At each time when the plants were observed, a record was made of the temperature and barometric pressure, and also of general weather conditions.

The records made at the time of each observation from 8 p.m. to 8 a.m. are presented in Table 1. The temperature records were taken at 8 a.m., and are the minimum temperatures during each preceding 24 hours. The term "blooming," as used in this table, indicates that the glumes are just beginning to open, or that the stamens and stigmas are emerging from the glumes, but that neither the filaments or stigmas have extended to full length. The relative number of flowers blooming at the time of each observation is indicated in the following way: None blooming; very few flowers blooming; few flowers blooming; medium number of flowers blooming; many flowers blooming; very many flowers blooming.

Several individual spikes on plants in other plots were also observed from the time when the first flower bloomed until the last had bloomed on each spike. On each morning, about sunrise, a photograph was made of one of these spikes. This series of photographs is shown in Plate XV.

The records presented in Table 1 show that at no time during the period over which these observations extended were flowers observed

TABLE 1.—*Number of timothy flowers blooming from June 22 to July 7, as recorded at two-hour intervals from 8 p.m. to 8 a.m.*

Date.	Minimum temperature. °F.	Barometric pressure at midnight.	Weather conditions.	Blooming record.						
				8 p.m.	10 p.m.	12 m.	2 a.m.	4 a.m.	6 a.m.	8 a.m.
June 22–23	68	......	Clear	......	None	Very few	Medium	Many	None	None
June 23–24	72	28.94	Do.	None	Very few	Do.	Many	Very few[a]	Do.	Do.
June 24–25	69	28.92	Do.	......	......	Do.	Do.	Few	Very few	Do.
June 25–26	68	29.10	Light rain	......	......	Do.	Do.	Many	None	Do.
June 26–27	65	28.90	Raining	......	None	Medium	......	Medium	Few	Do.
June 27–28	66	28.80	Clear	None	Do.	Very few	Medium	Do.	Small	......
June 28–29	54	28.80	Cloudy, windy	......	Do.	None	None	......	Very few	None
June 29–30	49	29.06	Clear, no wind	None	Do.	Do.	Do.	None	None	Do.
June 30–July 1	60	29.04	Cloudy, no wind	Do.	Few	Many	Very many	Do.	......	Do.[b]
July 1–2	60	28.80	Rain July 1, clear July 2	Do.	None	None	None	Do.	......	Do.[b]
July 2–3	53	29.05	Clear	......	Do.	Few	Many	Few	......	Do.[b]
July 3–4	52	29.06	Do.	None	Do.	......	None	......	Medium[a]	Do.[b]
July 4–5	57	29.08	Do.	......	Do.	Few	Very many	Medium	......	Do.[b]
July 5–6	56	29.10	Do.	......	[c]Do.	None	Medium	Many	......	Do.[b]
July 6–7	56	28.98	Do.	......	[c]Do.	Very few	Do.	Medium	None	......

[a] 5 a.m.

[b] 7 a.m.

[c] 9 p.m.

blooming in these plots at or before 8 p.m., though at 8 p.m. on June 30 one flower was found blooming on a plant in another plot. On nine of the eleven nights when observations were made at 10 p.m., no flowers were blooming; on two nights a relatively small number of flowers were blooming at that time. Flowers were found blooming at 12 o'clock on ten of the fourteen nights when observations were made at midnight, though on only one occasion were large numbers of flowers then blooming. At 2 a.m., as indicated in the table, the blooming process is about at its height. On five mornings the number of flowers blooming at 2 a.m. was greater than at 4 a.m.; while on only two dates, June 23 and July 6, were there a greater number of flowers blooming at 4 a.m. than at 2 a.m. On three of the nine mornings when the plants were observed at 6 a.m. a relatively small number of flowers were blooming, while on the remaining six mornings no flowers were blooming at that time. At no time were flowers observed blooming at 8 a.m. or later, in the plots for which records are presented in Table 1; on three or four occasions, however, a few scattering flowers were observed opening at that time on plants not growing in these plots.

The observations which have been made show that, as a rule, timothy flowers bloom in the greatest numbers from soon after midnight until about the time of or soon after sunrise.

CONDITIONS AFFECTING BLOOMING.

The actual time of the day when the greatest number of flowers bloom, varies to some extent. The total number of flowers that bloom on each day also varies greatly. On some days there is a very large number of flowers in bloom, while on other days but few or none are in bloom. This is illustrated in Plate XV, as well as in Table 1. Varying weather conditions are evidently the cause of these variations. Temperature variation is apparently the chief climatic factor affecting blooming.

The record presented in Table 1 shows that when the minimum temperature was 65° F. or higher timothy flowers continued to bloom in large numbers each day, whether the atmosphere was clear or whether it was cloudy and raining. Timothy flowers sometimes bloomed freely when the minimum temperature varied from 53° to 65° F., but the total number of flowers blooming was usually decreased or no flowers bloomed at all, especially when it rained or was cloudy and windy. When the minimum temperature was as low as 52° but comparatively few, and when at 49°, no flowers bloomed, although the atmosphere was clear and there was no wind on either morning when these temperatures occurred. It was observed that different plants varied somewhat in tendency to bloom at relatively low temperatures.

Whether timothy will bloom at temperatures somewhat below the optimum for blooming seems to depend to some extent upon the climatic conditions during the preceding days. On the morning of July 1, when the minimum temperature was 60°, after two days when the temperature had been comparatively low and when timothy had not bloomed, the flowers not only bloomed in very large numbers but also began to bloom earlier than is usually the case. Apparently at least a portion of the flowers which had not bloomed on the two preceding mornings, because of unfavorable temperature conditions, came into bloom on the morning of July 1, together with the flowers that ordinarily would have bloomed on the latter date, thus making the unusually large total number of flowers in bloom on one morning.

During the period from June 22 to July 7, the barometric pressure varied from 28.80 to 29.10. No correlation between the barometric pressure and the number of flowers blooming was observed.

There is a quite general popular belief that there are two distinct periods of bloom, which are often referred to as the "first" and the "second" bloom. The observations which have been made show that timothy flowers bloom on each day from the beginning of the blooming period until all of the flowers in the meadow have bloomed, except on days when the process is retarded by unfavorable climatic conditions.

Flowers Blooming on Culms Which Have Been Mown.

It has been observed that when timothy is mowed during the blooming period, the flowers sometimes bloom while the hay is laying in the swath. It has been found through repeated experiments that when timothy culms are cut during the late afternoon or evening, so that they do not become much wilted before sunset, the spikes will bloom on the following morning in about the same way as the spikes on growing plants. When the hay is lifted from the swath after sunrise, a cloud of pollen is frequently dislodged as the hay is shaken. Timothy cut during the morning on days when it is cloudy and raining and the hay wilts slowly, will sometimes bloom on the following morning, after the culms have been cut for nearly 24 hours. However, when timothy hay is cut during the early part of the day when the weather is dry and warm, as a rule the culms become dried out to such an extent that few or no flowers bloom on the following morning.

Color of Timothy Flowers in Bloom.

The most conspicuous part of a timothy flower in bloom is the anther. The changes in the appearance of a timothy field from day to day during the blooming period and at different times of the day are due largely to the changes in the number and condition of the anthers on the flowers in bloom. The stigmas and the filaments of the stamens have their own characteristic appearance, but are less conspicuous than the anthers.

There is considerable variation in the color of the anthers of timothy flowers at different times. In the early morning when the anthers emerge from the glumes the color is different than it is several hours later. The color of the anthers in the early morning is also different on some days than on others. Furthermore, the color of the anthers on different plants often varies on the same morning. When the weather is warm and the process of blooming has not been interrupted by unfavorable weather on preceding days, the anthers on the greater proportion of the plants are usually a delicate color, described in Ridgway's "Color Standards and Nomenclature"[5] as pale green yellow, or varying to light green yellow. When the weather is cool and wet or when the flowers have not been blooming freely on preceding mornings, the anthers on the greater proportion of the plants are likely to vary in color at time of blooming from Corinthian red to deep Corinthian red, or Indian red. On a small proportion of the plants, however, the color of the anthers at time of blooming is generally light yellow, whatever the weather conditions may be; and likewise, a small proportion of the plants produce red anthers on mornings when the anthers on the largest proportion of the plants are pale green yellow. Furthermore, it has been found that often when the anthers appear red, a careful examination will show that at the extreme tips, and sometimes also at the sides, an area which is light yellow in color may be found. The color of the anthers at time of blooming may be described as either a light tone of yellow or a deep tone of red, or it may be a combination of both colors. No other colors have been observed in anthers of timothy flowers at time of blooming.

After the anther sacs have become emptied of their contents and have been exposed to light for some time, a purple color begins to develop. The purple color develops more rapidly in bright sunshine than when the atmosphere is cloudy. It first begins to show as a delicate tint over the original light yellow or red color, and gradually increases in density until the color of the anther has become some marked tone of purple, which may be livid purple, deep livid purple, dark livid purple, or Corinthian purple. As a rule, the anthers which are light in color at time of blooming change to purple comparatively slowly, and do not become as dark purple as the anthers which were some tone of red at time of blooming.

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[5] Ridgway's "Color Standards and Nomenclature" was used to determine all color terms used in this report.

After the anthers of timothy flowers have been exposed to dew over night, or to rain, they lose all yellow, red, or purple coloration, and become a dull color, generally varying from tawny olive to Sayal brown.

The stigmas of the flowers are light gray, almost white, and show little change after blooming. The filaments are of about the same color as the stigmas but are quite inconspicuous.

Color of Timothy Meadows When the Flowers are in Bloom.

The color of a timothy meadow in bloom is always quite different from that of any particular part of the flower or plant.. It is the blended effect of the colors of the anthers, stigmas, and of the green background formed by the timothy spikes, culms, and leaves. The color of a meadow varies according to the number of flowers that have bloomed; according to the color of the anthers, as affected by the time of the day or by weather conditions; according to the proportion of new anthers and of anthers of preceding day's bloom, etc. The color is hardly the same at the same hour on any two days during the blooming season. On the morning of July 1, 1914, at 9 a.m.. after the timothy flowers had bloomed in very large numbers and but few anther sacs of preceding day's bloom were adhering to the spikes, the meadow presented a light purplish gray tone of color. This is perhaps most nearly the characteristic color of a timothy meadow after a few hours of sunshine, on mornings when the flowers have bloomed in large numbers. Early in the morning the color of the meadow may be affected by the yellow or red color of the anthers. At other times, large numbers of brown anther sacs of preceding days' bloom may have a marked effect upon the color of the meadow; on one such morning the color was near that described as light drab. On mornings when large numbers of flowers have bloomed and a wind has removed the anther sacs from the heads before the stigmas have dried up, the light colored stigmas sometimes produce a somewhat gray color over the meadow in bloom.

The changes in the color of timothy meadows during the time when the flowers bloom is the basis of a quite common popular belief that there are distinct stages during the blooming period, when the flowers are in the "purple bloom," "gray bloom," etc. The observations described here have shown that these variations in color may occur at any time when flowers bloom in large numbers in timothy meadows, and not at any particular stage during the blooming period.

SUMMARY.

When a timothy flower blooms, the anthers emerge first and then the stigmas. The anthers do not dehisce until the stigmas of the same flower have been exposed for some time.

The flowers growing in the upper portion of a timothy spike bloom first. Flowers lower on the spike come into bloom on succeeding days, the last to bloom being those growing near the base. The flowers on a single spike may continue to bloom from about 6 to 16 days.

The period during which timothy flowers bloom in meadows in northern Ohio extends from about June 16 or 20 to July 12 or 15. The period during which flowers are blooming in large numbers, however, is ordinarily about ten days, from June 24 or 26 to July 3 or 5.

The greatest number of flowers bloom in the early morning hours, from about midnight until about the time of or soon after sunrise. The number of flowers that bloom each day, and also to some extent the time of blooming, are affected by climatic conditions, especially temperature. Clear weather and a minimum temperature of about 60° F. or above are most favorable. Timothy flowers have not been observed blooming when the temperature during the preceding 24 hours was as low as 50° F.

When timothy hay is mown during the blooming period, the flowers will bloom 12 hours or more after the culms have been cut from the roots, provided that the hay has not become wilted or dry before the time of the day that blooming normally occurs.

The color of a timothy meadow in bloom varies greatly at different times during the blooming period. These changes are chiefly due to the changes in the color of the anther sac at different times and to the variation in the number of flowers that bloom on different days.

Except when unfavorable weather conditions exist, the blooming of timothy may be regarded as a process continuing without interruption from day to day, from the beginning to the end of the blooming period. The popular idea that there are two or more distinct stages in the blooming period, as the "first" and the "second" bloom, or the "blue" and the "gray" bloom, is manifestly incorrect.

CONTRIBUTIONS TO AGRONOMIC TERMINOLOGY—4.

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In the two preceding papers, the terms concerning the vegetative and reproductive portions of plants were discussed. In this paper, terms having to do with the surface covering and appearance of plants are enumerated and defined. These terms include those denoting (1) pubescence, (2) protuberances and inflations, (3) excretions, (4) punctations, and (5) perforations. Most of the terms are adjectives, though a few are nouns.

aculeate, *a.* Armed with prickles; echinate; prickly, as the rose and blackberry.

aculeolate, *a.* Armed with small prickles.

alveolate, *a.* Like honey comb.

antrorse, *a.* Directed upwards or forwards, as hairs at a node.

appressed, *a.* Pressed close to the stem.

arachnoid } *a.* Cobwebby; clothed with entangled hairs, as the base of the seed in various bluegrasses, especially Texas bluegrass.
araneose }

areolate, *a.* Marked out in little spaces.

argenteous } *a.* Silvery; like silver.
argentate }

aristate, *a.* Awned; tipped with one or more bristle-like appendages, as a wheat lemma or barley lemma or glume.

aristulate, *a.* Short-awned; diminutive of aristate.

asperous, *a.* Rough to the touch; scabrous.

awn, *n.* A bristle-like usually terminal appendage, as on the lemma in some varieties of barley, wheat, oats, etc.

awned, *a.* Furnished with one or more awns.

awn-pointed, *a.* Tipped with an awn.

bald, *a.* Destitute of hairs (physiological). Not properly used for *glabrous* (destitute of pubescence) or for awnless (without awns); calvous.

barbate, *a.* Bearing hairs or bristles in tufts like a beard, as on the nodes of some grasses or on the rachis or rachilla of oats; bearded.

barbed, *a.* Furnished with rigid points or short bristles usually reflexed like the barb of a fishhook, as the tip of each bristle on the fruit of the stickseed.

barbellate, *a.* Beset with short, stiff hairs, but shorter than when plumose.

barbellulate, *a.* Diminutive of barbellate.

barbulate, *a.* Finely bearded.

bristle, *n.* A sharp, stiff hair, or any very slender body of similar appearance; a seta.

bristly, *a.* Beset with bristles; setose.

bristle-pointed, *a.* Tipped with a bristle.

calvous, *a.* Bald or naked of hairs.

canaliculate, *a.* Longitudinally channeled.

canescent, *a.* Grayish-white; hoary, as when covered with fine, white hairs.

canous, *a.* Whitened with pubescence.

capillaceous
capillary } *a.* Hairlike in shape; as fine as a hair or bristle.

carene, *n.* A keel, or sharp longitudinal ridge.

carinate, *a.* Keeled.

cilium, *n.* A slender hairlike process.

ciliate, *a.* Fringed on the margin with hairs, like the eyelashes on the lids.

cobwebby, *a.* Arachnoid; bearing entangled hairs.

coma, *n.* A tuft, particularly a tuft of hairs.

comose, *a.* Furnished with a tuft of hairs, as the seed of milkweed, poplar, etc.

coriaceous, *a.* Leathery.

cribriform
cribrose } *a.* Pierced like a sieve with small apertures.

crinite, *a.* Bearing long hairs; shaggy.

cuspidate, *a.* Tipped with a short, sharp, rigid point or cusp.

downy, *n.* Clothed with a coat of soft, short hairs.

echinate, *a.* Armed with prickles; aculeate.

echinulate, *a.* Diminutive of echinate.

eglandulose, *a.* Destitute of glands.

erion, *n.* Greek for wool.

erianthous, *a.* Woolly-flowered.

eriophorous, *a.* Wool-bearing.

farinose, *a.* Covered with a mealy powder.

faveolate
favose } *a.* Honey-combed.

fenestrate, *a.* Pierced with one or more large openings.

filiform, *a.* Thread-shaped; long, slender and cylindrical.

fimbriate, *a.* Fringed; furnished with a fringe of hairs.

fimbrillate, *a.* Diminutive of fimbriate.

floccose, *a.* Composed of or bearing tufts of woolly or long and soft hairs.

foraminose, *a.* Pierced with openings.

foraminulose, *a.* Diminutive of foraminose.

foveate, *a.* Deeply pitted.

foveolate, *a.* Diminutive of foveate.

fringed, *a.* Beset on the margin with hairs or bristles.

furfuraceous, *a.* Covered with fine, flaky scurf.

glabrate, *a.* Almost glabrous; becoming glabrous with age.

glabrous, *a.* Without pubescence or prickles; smooth.

glandular, *a.* Beset with glands.

glaucescent, *a.* Slightly glaucous, or bluish-gray.

glaucous, *a.* Covered with a bloom; that is, with a whitish, waxy powder that rubs off, as that on a sorghum stalk or a cabbage leaf.

glochidiate
glochideous } *a.* Barbed at the tip; tipped with barbs.

glutinous, *a.* 1. Having the characteristics of glue; viscid; sticky.
2. Covered or pervaded with sticky matter.

gossypine, *a.* Cottony; flocculent.

gutta, *n.* A small drop-shaped marking.

guttate, *a.* Spotted, as if by drops of something colored.

hair, *n.* An outgrowth of the surface layer consisting of one or of several cells and very various in form.

hairy, *a.* Beset with hairs, especially longish hairs.

hamate
hamose } *a.* Hooked, as the end of a slender body bent around.

hamulose, *a.* Diminutive of hamose.

hispid, *a.* Beset with stiff hairs; bristly.

hispidulous, *a.* Diminutive of hispid.

hirsute, *a.* Clothed with rather coarse and stiffish hairs.

hirtellous
hirsutulous } *a.* Minutely hirsute.

hoary, *a.* Grayish-white; canescent.

holosericeous, *a.* Silky all over.

hooked, *a.* Hamate.

horn, *n.* A spur or similar appendage.

horny, *a.* Having the texture of horn.

incanous
incanescent } *a.* Hoary with soft, white pubescence.

indumentum
indument } *n.* Any hairy covering or pubescence.

induvite
induvial *a.* Clothed with old and withered parts.

keeled, *a.* Furnished with a keel or carene, or sharp longitudinal ridge; carinate.

lacunose, *a.* Full of holes or gaps.

laevigate, *a.* Smooth, as if polished.

lagopous, *a.* Densely clothed with long, soft hairs.

lanate
lanose *a.* Woolly; clothed with long, soft, tangled hairs.

lanuginous, *a.* Cottony or woolly.

leathery, *a.* Of the texture of leather; coriaceous.

maculate, *n.* Spotted or blotched, as the leaf of clover or geranium.

marmorate, *a.* Marbled.

mealy, *a.* Appearing as if covered with meal; farinose.

muricate, *a.* Beset with short and hard or prickly points.

muriculate, *a.* Diminutive of muricate.

nerved, *a.* Furnished with nerves or simple parallel veins.

nervose, *a.* Conspicuously nerved.

nervulose, *a.* Minutely nervose.

netted-veined, *a.* Reticulate.

nitid, *a.* Shining.

notate, *a.* Marked with spots or lines.

nodose, *a.* Knotty or knobby.

nodulose, *a.* Diminutive of nodose.

ocellate, *a.* Furnished with a circular patch resembling an eye.

oculate, *a.* Furnished with an eye-shaped marking.

opaque, *a.* (Surface.) Dull, not shining.

pannose, *a.* Covered with a felt of woolly hairs.

papilla, *n.* A little nipple-shaped protuberance.

papillate
papillose *a.* Covered with papillae.

penicillate
penicilliform *a.* Tipped with a tuft of fine hairs, as the stigmas of some grasses.

perforate, *a.* Pierced with holes, or having transparent dots resembling holes, as in an orange leaf.

pertuse, *a.* Perforated with a hole or slit.

piliferous, *a.* Beset with hairs; bearing a slender bristle or hair.

pilose, *a.* Covered with soft, slender hairs.

plumose, *a.* Feathery; said of any slender organ beset with hairs on its sides and resembling a feather.

prickly, *a.* Bearing prickles.

pruinose
pruinate *a.* Densely covered with white powder like frost.

puberulent, *a.* Covered with very fine, short, almost imperceptible pubescence.

pubescent, *a.* Hairy; especially with short, soft hairs.

pulverulent
pulverulaceous } *a.* Appearing as if dusted with fine powder.

pulvinus, *n.* A cushion; an enlargement or swelling, as at the base of the panicle branches in oats and sorghums.

punctate, *a.* Dotted, either with minute holes or dots resembling holes.

puncticulate, *a.* Diminutive of punctate.

pungent, *a.* Prickle-tipped.

pustulate, *a.* Covered with pustules or blisters.

ramentaceous, *a.* Beset with thin, chaffy squames, as the stalks of some ferns.

reticulate, *a.* In the form of a network; net-veined.

retrorse, *a.* Bent downwards or backwards.

rimose, *a.* Provided with cracks or chinks, as the bark of a chestnut tree.

rugose, *a.* Wrinkled; rough with wrinkles.

ruminate, *a.* Scored with irregular channels; looking as if chewed, as the nutmeg.

scabrous
scabrate } *a.* Roughened with minute points or elevations.

scabrid, *a.* Roughish; diminutively scabrous.

scrobiculate, *a.* Pitted; covered with shallow pits.

scurfy, *a.* Covered with scurf or fine squames.

sericeous, *a.* Silky; covered with satiny pubescence.

seta, *n.* A bristle, or slender bristle-like appendage.

setaceous, *a.* Bristle-like.

setigerous, *a.* Bearing bristles.

setose, *a.* Beset with bristles.

setula, *n.* A little bristle.

setulose, *a.* Beset with little bristles.

silky, *a.* Clothed with fine, soft, shiny, straight, appressed hairs.

silvery, *a.* Shining white or grayish-white, usually from silky pubescence.

smooth, *a.* Not rough; incorrectly used for glabrous (not pubescent), and for awnless or beardless (not awned). See also, *bald.*

spinose
spinous } *a.* Beset with spines; spiny.

spinulose, *a.* Diminutive of spinose.

spinescent, *a.* Becoming spiny in age.

spiniferous, *a.* Spine-bearing.

squamose
squamous *a.* Covered with or consisting of squames or of scales.

striate, *a.* Marked with slender, longitudinal lines or grooves.

striga, *n.* A short, sharp pointed, appressed, stiff hair, or hairlike squame.

strigose, *a.* Beset with stout, stiff, appressed bristles; provided with strigas.

strigillose, *a.* Diminutively or minutely strigose.

struma, *n.* A wen-like cushion or swelling, as on the distal end of a petiole.

strumose, *a.* Bearing a struma or swelling.

sulcate, *a.* Grooved with deep longitudinal furrows.

sulcus, *n.* A long, narrow channel or groove, as the furrow in the wheat or oat kernel.

thorny, *a.* Beset with thorns.

tomentose, *a.* Clothed with matted, woolly hairs or tomentum.

tomentum, *n.* A covering composed of matted, woolly hairs.

tubercle, *n.* A small excrescence, or pimple, especially if hard.

tuberculate, *a.* Bearing tubercles.

umbonate, *a.* Furnished with a low, rounded projection like a boss, or button.

unarmed, *a.* Destitute of prickles, spines, etc.

uncate, *a.* Uncinate.

uncinate, *a.* Hook-shaped; hooked at the end.

veined, *a.* Furnished with evident veins.

veiny, *a.* Veined.

velutinous, *a.* Velvety.

veinless, *a.* Without apparent veins.

venose, *a.* Strongly veined.

venulose, *a.* Veined with minute veins; diminutive of venose.

vernicose, *a.* Appearing as if varnished.

verrucose, *a.* Warty; covered with little wart-like projections.

vesicular, *a.* Bladdery.

vestiture, *n.* The clothing of a surface, as hairs or scales.

villose
villous *a.* Beset with long, soft hairs.

villosity, *n.* Villous pubescence.

viscous
viscid *a.* Having a glutinous or sticky surface.

wavy, *a.* Successively concave and convex.

waxy, *a.* Resembling wax.

woolly, *a.* Clothed with long and tangled, soft hairs.

THE EFFECT OF SOLUBLE NITROGENOUS SALTS ON NODULE FORMATION.[1]

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Introduction.

It has been known for a long time that the presence of certain salts in the soil has a tendency to retard the normal development of root nodules. This is especially true of the soluble salts of nitrogen, such as nitrates. If nodule production is retarded in the presence of nitrates or other soluble nitrogenous compounds, it naturally follows that less nitrogen will be assimilated from the atmosphere. Hence the ratio of the yield of dry matter to the gain in nitrogen with legumes grown in soil or sand low in soluble nitrogen will not be the same as that of legumes grown in rich soil. In order to measure accurately the nitrogen-assimilating power of a legume, it seems necessary to determine the amount of soluble nitrogen in the soil. This paper deals with the relation of combined nitrogen to the growth of legumes, *i. e.,* the effect of nitrates and ammonium sulfate on nodule production and nitrogen fixation.

It is apparent that there are many factors other than the soluble nitrogen content of the soil which may influence the nitrogen-gathering power of leguminous plants. Important among these agents may be mentioned soil type, reaction, species of plants, and non-nitrogenous fertilizers. Although the literature contains numerous examples of injury to nodules from soluble nitrogen, it has been noted frequently that in very rich garden soil plentifully supplied with nitrogen some of the common legumes as peas and beans are often abundantly inoculated. If nitrate nitrogen is detrimental, there must be some substance present in rich garden soil which tends to neutralize this action of nitrate.

Literature.

A review of the literature shows that a number of investigators have called attention to the effect of soluble nitrogenous compounds on the formation of root nodules. However, the practical significance of this factor as related to the nitrogen problem of cultivated soils has received but little consideration. It appears from the extensive literature on the subject of legume inoculation that the factors that influence nodule formation and assimilation of atmospheric nitrogen have been frequently noted. On the other hand, the nature and extent of the injury from nitrates and other soluble salts on nodule formation is far from solved.

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[1] Published with permission of the Director of the Wisconsin Agricultural Experiment Station. Received for publication June 26, 1916.

As far back as 1864 Rautenberg and Kühn (15)[2] noted that *Vicia faba* developed nodules in a solution free of soluble nitrogen, while in a solution containing soluble nitrogen no nodules were formed. Somewhat similar results were secured by Hugo de Vries (19) with red clover.

That the assimilation of free nitrogen by plants is closely related to the species of plant and to the fertility of soil was shown by Frank (4), who, working with lupines, peas, and clover, found that plants differ in their nitrogen-assimilating power under various soil conditions. He found that lupines can use nitrate nitrogen to advantage without any symbiotic relationship; that more nitrogen is assimilated when the plant is inoculated, and that the greatest amount of nitrogen is fixed from the air in the absence of nitrates. Experiments to determine the amount of nitrogen fixed from the atmosphere and the amount of nitrate nitrogen used from the soil failed on account of the destruction of nitrates in the soil. The use of ammonium sulfate gave similar results. Frank repeated these tests using peas, but the experiment partially failed because this plant would not grow in the presence of ammonium sulfate. His results indicated that peas differ from lupines in that the former will assimilate more nitrogen from the air in the presence of calcium nitrate than without any nitrate present. His results may be summarized as follows: (1) Peas developed large nodules in rich soil and fixed more nitrogen than lupines; (2) when thoroughly inoculated, clover assimilated large amounts of nitrogen in rich humus soil; (3) lupines fixed more nitrogen in poor soil than in rich soil.

The importance of soil type and fertility as related to nodule development was demonstrated by Wohltmann and Bergené (20), who observed that in soil containing 14 percent of humus and 0.3 percent of nitrogen no nodules occurred on the roots of peas. They worked with many classes of soils ranging from a poor sand low in organic matter and nitrogen to clays rich in organic matter. Their results indicated that organic nitrogen in the soil, except in the case of peat, had no appreciable effect on nodule formation. Nitrogen in the form of ammonium nitrate proved very detrimental. Mineral fertilizer, especially phosphorus and potassium salts, were beneficial.

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[2] Reference is made by number to "Literature cited," p. 327.

Schindler (16) pointed out that nodule development is smaller in clay soils than in sandy soils. He showed also that nodules are larger and more numerous in clay subsoil than in a rich compost. Beans planted in a rich garden soil produced large and numerous nodules; in a well manured soil only a few nodules were formed. Serradella failed to form nodules in a soil rich in lime.

In 1888 Vines (18) published his paper relating to the growth of nodules in the presence of nitrogenous salts. He found that nitrate nitrogen retards the development of nodules.

The gain in nitrogen resulting from the growth of legumes in the presence of nitrates has been studied by Woods (22). According to his results, the amount of nitrogen fixed is much less in the presence of calcium or potassium nitrate than in the controls to which no nitrate was added. This did not hold true for all plants. Beans, vetch, and cowpeas assimilated nitrogen in the presence of nitrates. In contrast to the results obtained by Woods, Baessler (1) demonstrated that in quartz, nitrogenous salts do not weaken the nitrogen-assimilating power of lupine bacteria.

Nobbe and Hiltner (11) in their extensive researches on cross-inoculation found that nodules have little influence on plant growth and nitrogen fixation so long as the plants have soil nitrogen in abundance.

Contrary to much of the data, Mazé (9) reports that in nutrient culture solutions *Bacillus radicicola* fixed nitrogen in a culture medium containing 1 percent of sodium nitrate. He claims that the decrease in nodule formation in rich soil is due to protein formation in the tissue. This causes a lack of carbohydrate and thus a decrease in number and size of nodules.

Hiltner (6) has presented data to show that in solution 5 milligrams of nitrogen as potassium nitrate per liter prevent nodule formation of peas. Ammonium sulfate also proved harmful. Nitrates were more harmful in sand than in rich soil. Moreover, he pointed out that if nodules are removed, assimilation of atmospheric nitrogen is reduced.

Similarly Nobbe and Richter (12) investigated the influence of nitrate nitrogen and humus on nodule production. They report that soy beans in rich garden soil gave an increase when inoculated of 74.7 percent. The percentage gain was considerably reduced when nitrates were applied. Where 500 milligrams of nitrate nitrogen were added to 4,000 grams of soil, the percentage gain was reduced to 69.1 percent. When larger amounts were added the percentage gain was correspondingly reduced. In the case of rich humus soil the gain due to inoculation amounted to 53.8 percent or 2.1 percent less than the inoculation in garden soil.

The results of experiments by Moore (10) indicated that alkaline nitrates in the proportion of 1 to 10,000 prevented nodule formation; also that bacteria when grown in media rich in nitrate not only lose their power of infection but also their power of assimilating atmospheric nitrogen.

Marchal (8) suggested that the antisymbiotic effect is not a specific property of nitrates but of all soluble soil salts. He obtained results to show that alkaline nitrates in concentrations of 1 to 10,000, ammonium salts in concentrations of 1 to 2,000, potassium salts 1 to 300, and sodium salts 1 to 200, injured nodule formation. Calcium and magnesium salts favored nodule formation.

Flamand (3) studied the effect of mineral nutrients on the production of root nodules of vetch and beans. He used potassium nitrate and sodium nitrate in various amounts and found that potassium nitrate in dilution of 1 to 10,000 and sodium nitrate in dilution of 1 to 2,000 retarded nodule development. Flamand was able to show that a nitrate salt will not act alike on all crops, *e. g.*, calcium nitrate injured nodule formation of beans much earlier than of vetch. Aside from nitrates, he reported that ammonium salts as well as sulfates retarded the formation of nodules. All legumes did not behave alike. Beans withstood a low dilution of ammonium nitrate and sulfate. Peptone proved slightly injurious when added in the same quantities as mineral salts, while urea did not show any injury.

In 1915 Kno (7) published a brief report concerning the influence of certain salts on nodule production in vetch. He found that calcium salts are essential for nodule formation in vetch.

Wilson's (21) results confirm the earlier work as regards the influence of nitrates on nodule production. The presence of sulfates in a relatively weak concentration seems to inhibit the nodule production of soy beans. He found, in addition, that chlorides and phosphates stimulate nodule production, while ammonium salts are inhibitory. Development was prevented by the presence of nitrates and ammonium salts, but the organisms retained their vitality in the presence of these salts.

According to Prucha (14) small amounts of potassium nitrate, calcium nitrate, ferric nitrate, ferric chloride, ammonium chloride, potassium chloride, and peptone inhibit nodule development, while the addition of tannic acid, magnesium sulfate, monopotassium phosphate, potassium hydroxide, dicalcium phosphate, and calcium sulfate show a beneficial effect.

Creydt (2) found that the addition of sodium nitrate or ammonium sulfate to soil greatly injured nodule formation of yellow lupines. Aside from soluble nitrogen, he noted that the presence of calcium carbonate in soil hindered the formation of lupine nodules. Apparently the root tubercles from soil rich in carbonate of lime occur isolated on the tip of the tap or side roots, while in soil poor in carbonate of lime they occur crowded on the upper part of the tap root.

Somewhat similar investigations by Seelhorst, Geilmann, and Thiele (17) indicate that the sensitiveness of lupines to lime is due not only to the direct injury of the plant itself, but also to the cooperating bacteria.

According to Pfeiffer and Blanck (13), limestone injures nodule formation and nitrogen assimilation of lupines. When nitrate salts were added the harmful effect was even more marked.

From the foregoing resumé of the factors that influence nodule formation, it is evident that nitrate nitrogen in the soil plays an important part in the assimilation of atmospheric nitrogen by leguminous plants. No doubt the nitrogen assimilation of the common legumes is largely affected by the presence of soluble nitrogen. The results of numerous experiments support this statement.

EXPERIMENTAL WORK AND RESULTS.

THE EFFECT OF ADDED NITRATES ON GROWTH AND NITROGEN CONTENT OF ALFALFA AND VETCH IN SAND CULTURES.

Since nodules are associated with nitrogen assimilation, it is of interest to study the influence of nitrates not only on nodule production but on the subsequent gain in nitrogen. A series of experiments was made in which the type of plant, kind of soil, and amount of soluble nitrogen were varied.

The Effect of Ammonium Nitrate of Nodule Formation in Sand.

Forty small glazed jars, 3-kilo capacity, were filled with white quartz sand and a nutrient plant solution added. Each jar received the same amount of nutrient salts with the exception of nitrogen. This was added in varying amounts as given in Table 1. At regular intervals of one week each, the nutrient solution was renewed. A pure culture of the legume bacteria on agar was used to inoculate.

In order to prevent cross-inoculation, the jars were kept in a special glass house, protected from dust and insects. The plants were watered with distilled water. In the jars free of nitrogen very little growth was noted. Apparently a small amount of combined nitrogen is needed for the development of the young seedlings. The data of this test are presented in Table 1.

TABLE 1.—*Effect of inoculation with and without nitrates on the growth and nitrogen content of alfalfa and vetch.*

No.	Milligrams of N as nitrate per 100 c. c. of solution.	Treatment.	Tops.		Roots.		Nodule occurrence.
			Dry weight.	Nitrogen in 1 gram.	Dry weight.	Nitrogen in 1 gram.	
ALFALFA.			*Grams.*	*Mgm.*	*Grams.*	*Mgm.*	
1	None	Uninoculated	0.1	22.3	0.3	15.6	None
2	None	Inoculated	0.3	24.5	0.2	22.7	Numerous
3	1	Uninoculated	0.8	20.0	0.8	16.8	None
4	1	Inoculated	1.4	28.8	1.5	18.9	Numerous
5	5	Uninoculated	3.8	26.4	3.0	19.0	None
6	5	Inoculated	3.9	32.9	2.5	28.8	Numerous
7	10	Uninoculated	5.5	39.3	2.8	34.3	None
8	10	Inoculated	4.9	33.8	2.3	30.4	Few
9	15	Uninoculated	3.7	54.7	1.5	44.9	None
10	15	Inoculated	5.6	52.2	2.5	54.6	None
VETCH.							
11	None	Uninoculated	0.6	22.2	1.8	29.1	None
12	None	Inoculated	4.0	44.9	2.4	22.3	Numerous
13	1	Uninoculated	3.4	26.5	2.0	15.9	One
14	1	Inoculated	4.9	38.6	6.7	14.4	Numerous
15	5	Uninoculated	5.0	31.2	4.2	24.8	None
16	5	Inoculated	5.9	41.3	3.5	28.1	Few
17	10	Uninoculated	7.4	46.3	2.5	29.9	None
18	10	Inoculated	7.4	47.3	2.5	36.9	Very few
19	15	Uninoculated	3.9	60.8	1.2	37.1	None
20	15	Inoculated	4.0	63.0	1.5	45.8	None

From the figures in Table 1 it is very apparent that inoculation alone or inoculation in the presence of small amounts of ammonium nitrate, 1 to 5 milligrams, causes an increase in growth of the parts above ground and in percentage of nitrogen. The benefit derived from the presence of the proper bacteria is noticeable both with alfalfa and vetch. When larger quantities of nitrogen were added, 10 milligrams, the favorable effect of inoculation was suppressed, although the inoculated vetch plants showed a somewhat higher nitrogen content. In the series to which 15 milligrams of nitrate nitrogen were added, the inoculated plants were somewhat larger, although no consistent increase in percentage of nitrogen was noted. The uninoculated alfalfa in the presence of 15 milligrams of nitrate nitrogen gave the highest percentage of nitrogen in the dry matter. In the case of vetch the reverse is true. A comparison of the dry weights and the percentage of nitrogen in alfalfa roots shows that there is in almost every case a marked gain due to inoculation. This does not hold true in the presence of large amounts of nitrate nitrogen. The vetch series behaved somewhat differently. Here the inoculated roots showed a gain in weight without or in the presence of 1 milligram of nitrogen from nitrate.

Turning to the notes on nodule formation, the last column of Table 1, the effect of nitrate nitrogen as ammonium nitrate on nodule formation is very evident. Wherever the proper bacteria were added profuse nodule formation was noted except in the presence of large amounts of soluble nitrogen. This is equally true of the plants from both series, although the alfalfa seems more resistant to nitrates than vetch.

In the uninoculated series no nodules were formed except in pot 13 of the vetch series.

From the data as a whole, two facts stand out very prominently: (1) In the absence or presence of small amounts of combined nitrogen, pure cultures of *Bacillus radicicola* form nodules in great numbers on alfalfa and vetch; (2) in the presence of larger amounts of nitrate nitrogen the legume bacteria do not possess the power of forming nodules, at least only in rare cases.

In view of the very poor growth of alfalfa and vetch in the absence of combined nitrogen, it seems that small amounts of combined nitrogen are favorable to plant growth and nitrogen assimilation.

The Effect of Calcium Nitrate on Nodule Formation in a Mixture of Soil and Sand.

The following experiment was made to determine whether or not a change in the physical and chemical constituents of the medium would influence nodule formation.

In this test the seed bed was prepared by mixing one part of a rich garden soil with nine parts of pure silica sand. The nutrient solution other than nitrogen was added in solid form. Each of 16 two-gallon jars containing 11,100 grams of the dry mixture received 2 grams of potassium chloride (KCl), 1.6 grams of magnesium sulfate ($MgSO_4$), 1.0 gram of monopotassium phosphate (KH_2PO_4), and 12 grams of tricalcium phosphate [$Ca_3(PO_4)_2$]. The soils and jars were sterilized in the steam autoclave for one hour at 30 pounds pressure. Half of the jars were inoculated with a pure culture of vetch bacteria, the other half were uninoculated. Along with the sand-soil series or mixture, 8 jars were filled with pure silica sand and treated in the same manner as the previous series. The nitrate was added in the form of calcium nitrate, $Ca(NO_3)_2$. The moisture was kept at 60 percent saturation. All of the 24 jars were planted to vetch, using 15 seeds per jar. Unfortunately the vetch failed to germinate uniformly. Later these seedlings were removed and the jars again planted to vetch. Here again the vetch grew poorly. At this season of the year, November to January, it is not surprising that vetch grew very sparsely and was subject to the attack of many greenhouse pests. The crop was harvested in January and notes made on the occurrence of nodules. The results are presented in Table 2.

TABLE 2.—*Effect of calcium nitrate on nodule formation with vetch and soy beans.*

No.	Soil.	Milligrams of N as nitrate per 100 grams of soil.	Treatment.	Nodule formation on vetch, Nov. 7 to Jan. 2.	Soy beans, Feb. 15 to April 10.	
					Notes on nodules.	Condition of crop.
1	Mixture	0	Uninoculated	Numerous	None	Deep green, healthy
2	Do.	0	Do.	None	Do.	Do.
3	Quartz	0	Do.	Do.	Do.	Do.
4	Mixture	0	Inoculated	Very numerous	Numerous	Do.
5	Do.	0	Do.	Do.	Do.	Do.
6	Quartz	0	Do.	Do.	Do.	Do.
7	Mixture	2	Uninoculated	2 nodules	None	Light green
8	Do.	2	Do.	8 nodules	Do.	Do.
9	Quartz	2	Do.	None	Do.	Yellow
10	Mixture	2	Inoculated	Numerous, small	Few, small	Deep green
11	Do.	2	Do.	Do.	Do.	Do.
12	Quartz	2	Do.	Do.	Do.	Do.
13	Mixture	5	Uninoculated	1 nodule	None	Light green
14	Do.	5	Do.	4 nodules	Do.	Do.
15	Quartz	5	Do.	None	Do.	Do.
16	Mixture	5	Inoculated	51 nodules	Do.	One plant
17	Do.	5	Do.	28 nodules	No plants	No plants
18	Quartz	5	Do.	38 nodules	No nodules	Green
19	Mixture	10	Uninoculated	None	None	No plants
20	Do.	10	Do.	Do.	Do.	Few plants
21	Quartz	10	Do.	Do.	Do.	Do.
22	Mixture	10	Inoculated	16 nodules, small	Do.	Do.
23	Do.	10	Do.	12 nodules	Do.	No plants
24	Quartz	10	Do.	No plants	Do.	Do.

Although several of the uninoculated jars became infected, the data as a whole show the detrimental effect of large amounts of nitrate nitrogen on nodule formation. Apparently soluble nitrogen is not so injurious in a mixture of sand and soil as in sand alone.

In February the same 24 jars were planted to soy beans, 5 seeds per jar. After the plants had a good start, nitrate nitrogen was added to the jars in the same quantities as at the beginning. The plants grew well where the nitrate content was low. In the presence of large amounts of nitrate the soy beans soon died. All of the plants were thoroughly inoculated where pure cultures were added. The data with reference to number of nodules and conditions of crop when harvested are given in Table 2.

It will be seen from the results recorded in Table 2 that as the amount of nitrate nitrogen in the soil is increased, the degree of inoculation is decreased. Inoculation without nitrate resulted in the formation of large and numerous nodules on soy beans. When 2 milligrams of nitrate nitrogen were added to the soil, the nodules were still numerous but smaller. In the presence of 5 milligrams of nitrate nitrogen, the soy beans grew very slowly.

The Effect of Sodium Nitrate and Ammonium Sulfate on Alfalfa and Crimson Clover in Miami Silt Loam.

For this experiment 28 two-gallon jars were filled with 8,000 grams of dry Miami silt loam soil. Nitrate nitrogen in the form of sodium nitrate ($NaNO_3$) and ammonium sulfate [$(NH_4)_2SO_4$] was added in amounts as shown in Table 3. The soil was kept at 60 percent saturation for two weeks and then sown to alfalfa and crimson clover respectively. Pure cultures of the proper bacteria were used to inoculate the seeds. This series was allowed to grow for 74 days. After the portion above ground was harvested, the roots were removed and nodules counted. At the same time the crop was cut, nitrate analyses were made of the soil. These jars were then sown, the alfalfa series to medium red clover and the crimson clover series to alfalfa. The same procedure was followed as given in the previous series. Nitrate nitrogen was again determined at the end of the experiment. The results obtained from this study are recorded in Table 3.

The difference between the number of nodules in the presence of sodium nitrate and ammonium sulfate is shown very clearly in the figures of the alfalfa group, first crop (Table 3). Apparently the nitrate salt is much more injurious to nodule formation than the sulfate.

In agreement with the results of previous experiments, nitrate nitrogen influenced nodule development to a great extent. The effect was most noticeable on crimson clover. As compared with the results secured in sand or sand and soil mixture, it seems that inoculation with legume bacteria is much less sensitive to nitrate nitrogen in soil than in sand. After adding 30 milligrams nitrate nitrogen to the soil the plants failed to grow. The effect on nodule formation was least noticeable on medium red clover. However, the dry weight of the tops was reduced to a greater extent than in alfalfa. As a general rule, the same amount of nitrogen from ammonium sulfate was less harmful than that from sodium nitrate.

TABLE 3.—*Effect of sodium nitrate and ammonium sulfate on nodule formation.*

Pot No.	Treatment per 100 grams of soil.	Nodules on 10 plants.[a]	Milligrams of nitrate nitrogen in 100 grams of soil on Dec. 31.	Nodules on 10 plants.[b]	Milligrams of nitrate nitrogen in 100 grams of soil on June 20.
		ALFALFA.		RED CLOVER.	
1	None	43	5.5	Numerous	3.8
2	Do.	20	6.6	Do.	3.8
3	10 mgm. nitrogen from $NaNO_3$	3	8.6	Do.	5.0
4	Do.	6	25.0	Do.	8.3
5	10 mgm. nitrogen from $(NH_4)_2SO_4$	12	9.4	Do.	10.0
6	Do.	32	8.6	Do.	9.2
7	30 mgm. nitrogen from $NaNO_3$	6	26.3	Few	25.0
8	Do.	11	20.8	Do.	27.7
9	30 mgm. nitrogen from $(NH_4)_2SO_4$	16	30.0	Do.	25.0
10	Do.	13	30.0	Do.	25.0
11	50 mgm. nitrogen from $NaNO_3$	No plants	47.1	None	41.6
12	Do.	None	35.7	Do.	35.7
13	50 mgm. nitrogen from $(NH_4)_2SO_4$	8	8.0	Do.	41.6
14	Do.	4	41.0		
		CRIMSON CLOVER.		ALFALFA.	
15	None	Numerous	8.9	Numerous	4.3
16	Do.	Do.	6.4	Do.	3.1
17	10 mgm. nitrogen from $NaNO_3$	4	15.1	Do.	3.5
18	Do.	Numerous	15.6	Do.	6.6
19	10 mgm. nitrogen from $(NH_4)_2SO_4$	Numerous, small	9.4	Do.	3.3
20	Do.	Do.	9.4	Do.	5.0
21	30 mgm. nitrogen from $NaNO_3$	No plants	29.4	Few	25.0
22	Do.	Do.	23.3	Numerous, small	14.2
23	30 mgm. nitrogen from $(NH_4)_2SO_4$	Do.	25.0	Do.	10.0
24	Do.	Do.	31.2	Few	18.5
25	50 mgm. nitrogen from $NaNO_3$	Do.		Do.	27.2
26	Do.	Do.	55.5	Do.	31.0
27	50 mgm. nitrogen from $(NH_4)_2SO_4$	Do.	29.4	Very few	33.0
28	Do.	Do.	25.0	Do.	31.0

[a] Period of growth October 18 to December 31.

[b] Period of growth March 5 to June 20.

The Effect of Accumulated Nitrates in Various Soils on Nodule Formation.

For this experiment nitrates were allowed to accumulate in neutral Miami silt loam, acid Colby silt loam, and acid peat for nearly one year. A portion of the soil was then transferred to half-gallon jars and sown to alfalfa and vetch. The control jars were filled with fresh soil and likewise sown to alfalfa and vetch. The seeds were thoroughly inoculated before they were sown. Optimum moisture conditions prevailed throughout the experiment. After the plants had reached maximum growth they were removed and the roots carefully examined for number and size of nodules. The plants in the peat series failed to develop. In view of the high nitrate content of the peat, about 70 milligrams of nitrate nitrogen per 100 grams of soil, this is not surprising. The results of this test are given in Table 4.

Apparently nitrates are injurious to nodule formation, both in acid and neutral soils. Moreover, accumulated nitrates have the same general effect as added nitrates. This point is of special interest in connection with the possible significance of accumulated nitrates on the process of nitrogen assimilation.

Table 4.—*Effect of accumulated nitrates on nodule formation.*

Pot No.	Soil type.	Crop.	Nitrate nitrogen in 100 grams of soil.		Nodule formation.	Color of plant.
			At beginning.	At end.		
			Mgm.	*Mgm.*		
1	Fresh Colby silt loam	Alfalfa	3.04	3.41	None	Green
2	Do.	Do.	3.04	1.39	Few	Do.
3	Do.	Vetch	3.04	1.91	Numerous	Do.
4	Do.	Do.	3.04	0.85	Do.	Do.
5	Old Colby silt loam	Alfalfa	17.35	10.83	Very few	Deep green
6	Do.	Do.	17.35	10.55	Do.	Do.
7	Do.	Vetch	22.30	12.73	Do.	Do.
8	Do.	Do.	22.30	12.92	Do.	Do.
9	Fresh Miami silt loam	Alfalfa	2.00	1.25	Numerous	Green
10	Do.	Do.	2.00	1.08	Do.	Do.
11	Do.	Vetch	2.00	1.87	Do.	Do.
12	Do.	Do.	2.00	1.83	Do.	Do.
13	Old Miami silt loam	Alfalfa	23.10	9.69	Very few, small	Deep green
14	Do.	Do.	23.10	10.81	Do.	Do.
15	Do.	Vetch	23.10	10.68	Do.	Do.
16	Do.	Do.	23.10	12.00	Do.	Do.

Discussion.

From a general review of the data, it seems safe to conclude that under field conditions nitrates rarely, if ever, occur in amounts great enough to prohibit nodule formation. However, it is very probable that the percentage gain of nitrogen of legumes is injured by the presence of soluble nitrogen. The nitrogen-assimilating power of legumes in the presence of soluble salts seems to depend upon many factors, as the physical, chemical, and biological composition of the soil, species of plant, etc. Very probably the presence of an abundance of moisture is beneficial to nodule formation in two or more ways: (1) water is necessary for the normal function of the plant and bacteria; (2) water tends to leach out the soluble nitrogen. The importance of soil moisture for root tubercles has been noted by Gain (5) and others. These observations on certain of the factors that influence nodule production suggest that possibly many of the statements commonly published concerning nitrogen-assimilation by legumes grown in sand or soil culture very low in nitrogen will not hold true under field conditions. It seems safe to conclude that, in order to secure the maximum growth as well as maximum gain in nitrogen from legumes, a small amount of soluble nitrogen is beneficial, while large amounts are detrimental.

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THE EFFECT OF CLIPPING ON THE ROOT DEVELOPMENT OF ALFALFA.[1]

ROLAND McKEE,

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In the spring of 1912 an experiment was started at Chico, Cal., to determine the effect on the root development of alfalfa of clipping the tops the first year. Seed of ordinary alfalfa was sown May 6 in two rows each 60 feet long and 4 feet apart. As nothing was planted closer than 20 feet on either side of the rows, the plants had an equal chance for development so far as space was concerned. No weeds were allowed to grow and the only difference in the treatment of the rows was in the matter of clipping. One of the rows was allowed to grow throughout the season undisturbed while the other was clipped on July 13 and September 1. The plants were all dug October 10 and the diameter of the roots immediately below the crown measured.

The row not clipped contained 104 plants. The total diameter of the roots was 1,100 mm., or an average diameter of 10.48 mm. The row clipped contained 116 plants. The total diameter of the roots was 867 mm., or an average diameter of 7.49 mm. The greater diameter of the unclipped plants was very marked.

In 1913 the experiments as carried out in 1912 was repeated. However, in this year the row plantings were made in triplicate to insure accuracy. As in 1912 the plants of the rows not clipped had decidedly the larger roots, though the difference was not as great as in 1912. The average diameter of the roots of the clipped row having the greatest average diameter was 0.77 mm. less than the average diameter of the roots of the unclipped row having the smallest average diameter. The data obtained in 1912 and 1913 are assembled in Table 1.

In addition to the row plantings plot plantings were made in 1913. Eight plots each containing 128 sq. ft. were planted April 21. The seed was planted in 2-inch squares in an attempt to have the plants uniformly spaced, but on account of poor germination the plants were on the average farther apart than 2 inches. However, the stand was

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[1] Received for publication April 12, 1916.

TABLE 1.—*Data on root development of clipped and unclipped alfalfa plants in rows, at Chico, Cal., in 1912 and 1913.*

Year.	Treatment.	Length of row.	Average space per plant.	Total number of roots.	Total diameter.	Average diameter.	Diameter of largest root.
		Feet.	*Sq. in.*		*mm.*	*mm.*	*mm.*
1912	Clipped	60	6.2	116	867	7.49	—
1912	Not clipped	60	6.9	104	1,100	10.48	—
1913	Clipped	[a]180	—	152	1,670	10.98	17
1913	Not clipped	[a]180	—	218	2,814	12.90	25

[a] Sixty-foot rows repeated 3 times.

quite uniform over all the plots, and appeared as an ordinary field stand of alfalfa. Four of the plots were clipped July 8 and again September 2, while the remaining four plots were allowed to make continuous growth throughout the season. A border 24 inches wide was planted about the plots to eliminate border effects. The plants were all dug October 9 and the diameter of the roots measured as in the row plantings. The average diameter of the roots clipped was 6.56 mm., and of the roots not clipped 6.91 mm.

In 1914 plot plantings were made as in 1913 except that the seed was sown broadcast instead of being definitely spaced in planting. A stand was secured that was representative of a good field stand. The plots were repeated six times. One of the series of plots was clipped July 10 and again August 24; the other was left uncut throughout the season. The plants were dug and the roots measured October 20. The plants clipped had an average root diameter of 6.34 mm., while the ones not clipped had an average diameter of 6.93 mm. The data on the plot plantings in 1913 and 1914 are given in Table 2.

TABLE 2.—*Data on root development of clipped and unclipped alfalfa plants in plots, at Chico, Cal., in 1913 and 1914.*

Year.	Treatment.	Total area.	Area per plant.	Total no. of roots.	Total diameter.	Average diameter.	Diameter of largest root.
		Sq. ft.	*Sq. in.*		*mm.*	*mm.*	*mm.*
1913	Clipped	[a]512	45.53	1,619	10,622	6.56	15 x 16
1913	Not clipped	[a]512	40.42	1,824	12,617	6.91	21 x 25
1914	Clipped	[b] 96	25.90	977	6,198	6.34	14 x 17
1914	Not clipped	[b] 96	25.00	1,013	7,027	6.93	16 x 19

[a] Plots of 128 sq. ft. repeated 4 times.

[b] Plots of 16 sq. ft. repeated 6 times.

In all the experiments the plants were grown without irrigation. Owing to the dry weather conditions prevailing at Chico throughout the summer, the growth was not large in any case, the yield from the best plots being about 1 ton per acre.

These data representing three years' work indicate that root development is retarded by reason of clipping alfalfa plants the first year, and it seems probable that this retarded development may result in decreased hay yields in the first and second seasons if not in subsequent years. However, very little work has been done to determine the effect of clipping on subsequent hay yields. Piper[2] reports several cases where weakened growth and decreased yields of alfalfa in the second year was apparently due to clipping the first season, and advises that clipping should not be done except in cases where it is necessary to overcome weed growth. Some of the State experiment stations also have advised against clipping, while others claim beneficial effects, not only in the control of weeds but also in invigorated growth and greater root development.

Coburn,[3] quoting the editor of the Nebraska Farmer, says:

> Nine tenths of the failures with alfalfa have been due to failure or neglect to cut it as should have been done when young. This is the law of alfalfa culture; it must be cut down. And the man who has not the courage, morally and physically, to use a mowing machine persistently, had best pass by alfalfa culture. It takes moral courage to cut baby alfalfa; but it must be cut down to save it.

Olin,[4] in giving directions regarding handling alfalfa the first year, writes as follows:

> Clip young alfalfa often enough to keep down weeds this first season. It checks weeds but invigorates the alfalfa. This has a tendency to keep down stem growth and invigorate root growth of the plant. Do not clip so close to the ground as to remove too much of the leafy growth, for there must be sufficient leaves remaining to elaborate the plant food required by the whole plant. When this is done clipping acts like a tonic on alfalfa. . . . It is neither hay nor seed we want this first year but a sturdy, unchecked, vigorous root growth.

Wing[5] advises the cutting of alfalfa in order to keep it in thrift. However, he qualifies his statement by saying that "this is especially true in the region east of the Missouri River."

[2] Piper, C. V. Forage Plants and Their Culture. 1914.

[3] Coburn, F. D. The Book of Alfalfa. 1907.

[4] Olin, W. H. American Irrigation Farming. 1913.

[5] Wing, J. E. Alfalfa Farming in America. 1909.

The statements of Coburn, Olin, and Wing are not supported by any cited experimental evidence, and there seem to be no experimental data in other publications to justify the conclusion that clipping in itself is a direct stimulant to the plant or that it induces root development. It perhaps is true that clipping is sometimes essential, and it certainly is the most economical means of reducing weed growth. However, that there are beneficial effects due to clipping alone when the plants are making normal growth seems never to have been proven.

The data of the work at Chico, Cal., are presented with the idea of suggesting further work along this line to determine more definitely the relation between clipping alfalfa the first year and the yield of hay in subsequent years.

AGRONOMIC AFFAIRS.

MEETINGS OF THE SOCIETY.

The annual meeting of the American Society of Agronomy, as previously noted, will be held in Washington, D. C., on Monday, November 13, and Tuesday, November 14, 1916. It was hoped that a tentative program for the meeting could be printed in the present issue, but the number of titles for papers in hand as this is written is insufficient for the complete program. It is the intention, however, to hold two joint sessions with the Society for the Promotion of Agricultural Science and the American Farm-Management Association. The first of these will be held on Monday evening, November 13, when the presidential addresses of the three societies will be delivered. The second will be held on Tuesday afternoon, November 14, when a general program will be presented by members of the three organizations concerned. The sessions on Monday afternoon and Tuesday morning will be separate from those of any other organization; the business session will probably be held at the close of the program session on Tuesday morning.

Because of several conditions over which the officers of the Great Plains Cooperative Association and the American Society of Agronomy had no control, it seemed undesirable to hold the joint meeting of these two organizations which was announced for Amarillo, Tex., on August 22–24. Notification of this fact was sent to the members of this Society in the Great Plains early in August.

MEMBERSHIP CHANGES.

The total membership of the Society reported in the July–August issue was 570. Nine new members have been added since that issue went to press, making the total at this time 579. The names and addresses of these new members and of those whose addresses have been changed during the past two months are reported herewith.

New Members.

Albrecht, William A., 709 S. First St., Champaign, Ill.
Chapman, I. N., Kans. State Agr. College, Manhattan, Kans.
Dustman, Robert B., Dept. of Soils, Expt. Sta., Morgantown, W. Va.
Lofinck, R. E., Kans. State Agr. College, Manhattan, Kans.
McAdams, James, Kans. State Agr. College, Manhattan, Kans.

Mally, F. W., Laredo, Tex.
Milner, F. W., Hartford, Kans.
Salter, Robert M., Dept. of Soils, Expt. Sta., Morgantown, W. Va.
Weisbein, Isaac, 315 Dryden Road, Ithaca, N. Y.

Changed Addresses.

Bailey, C. H., Chem. Lab., Minn. Grain Insp. Dept., Minneapolis, Minn.
Bear, Firman E., Townshend Hall, O. S. U., Columbus, Ohio.
Bledsoe, R. Page, Dept. Agron., College of Agr., Berkeley, Cal.
Burnett, Grover, University of Idaho, Moscow, Idaho.
Burr, W. W., University of Nebraska, Lincoln, Nebr.
Bushey, A. L., Castlewood, S. Dak.
Chapman, James E., 2316 Pierce Ave., St. Anthony Park, St. Paul, Minn.
Cook, I. S., Jr., Wheeling Commercial Association, Wheeling, W. Va.
Etheridge, W. C., Experiment Station, Columbia, Mo.
Israelson, Orson W., College of Agriculture, Logan, Utah.
McCall, Arthur G., Maryland Expt. Sta., College Park, Md.
Miyake, Kōji, 1300 Vermont Ave., Washington, D. C.
Morgan, G. W., Havre, Mont.
Myer, D. S., County Agent, Evansville, Ind.
Parker, J. H., University Farm, St. Paul, Minn.
Voigt, Edwin, 222 N. 32d St., Camden, N. J.
Wheeler, W. A., Office of Markets, U. S. Dept. Agr., Washington, D. C.
Widtsoe, John A., University of Utah, Salt Lake City, Utah.

NOTES AND NEWS.

W. E. Ayres has been appointed assistant in agronomy at the Arkansas station.

Firman E. Bear, professor of soils in the University of West Virginia, has been elected to a similar position in Ohio State University and assumed his duties with the beginning of the college year.

W. O. Collins has been elected instructor in soil chemistry and W. H. Collins instructor in agronomy in the Georgia college.

W. C. Etheridge, for the past year professor of agronomy in the University of Florida, has succeeded C. B. Hutchison as professor of farm crops in the University of Missouri. Professor Hutchison, as previously noted, will devote a year to graduate study, after which he will become associated with the plant-breeding department of Cornell University.

A. R. Mann, editor of the Cornell University station, has been elected acting dean and director of the college of agriculture and the experiment station of Cornell University. He assumed his duties on August 1.

Jay B. Park, formerly of the Illinois station and for the past two years engaged in graduate study in plant breeding at Bussey Institute, is now professor of farm crops in Ohio State University.

J. E. Turlington of the Farm Life School, Vanceboro, N. C., has succeeded W. C. Etheridge as professor of farm crops in the University of Florida.

R. M. West, assistant professor of agricultural chemistry and assistant chemist of the Minnesota college and station, was appointed secretary of the Minnesota State Department of Agriculture on March 1.

W. A. Wheeler, formerly botanist of the South Dakota college and station and for the past several years manager of the Dakota Improved Seed Company at Mitchell, S. Dak., on July 1 became a specialist in seed marketing in the Federal Office of Markets.

J. J. Willaman has been promoted from instructor to assistant professor of agricultural chemistry in the University of Minnesota.

The eleventh International Soil Products Exposition will be held at El Paso, Tex., October 17 to 26, 1916. The annual sessions of the International Dry-Farming Congress and the International Irrigation Congress will be held during the exposition. Among the speakers announced for these meetings are President Wilson, Secretary of the Interior Franklin K. Lane, and Secretary of Agriculture David F. Houston.

THE INTERSTATE CEREAL CONFERENCE.

The second Interstate Cereal Conference was held at the University of Minnesota, University Farm, St. Paul, July 11, 12, and 13, 1916. In the absence of Prof. J. W. Gilmore, chairman of the executive committee, Dr. R. W. Thatcher was elected chairman of the conference. The total attendance at the different sessions numbered 55, of whom 19 were from the University of Minnesota, 9 from the U. S. Department of Agriculture, 3 from the Minnesota Grain Inspection Department, 3 from the Wisconsin experiment station, 1 each from the Colorado, Illinois, Iowa, Montana, and North Dakota stations, and 16 from various commercial concerns, including 5 flour mills, a malting company, a linseed oil company, a grain company, a commercial laboratory, a crop bureau, a bakery, and a milling journal.

Morning and afternoon sessions were held at University Farm on July 11 and a morning session on July 12. At these sessions 17 papers were presented, the topics including problems of wheat, oat, barley, and flax production in the northwest; the grading of barley and corn; ergot of rye; problems in flax diseases; breeding winter wheat for Minnesota; and milling and baking subjects and problems. The afternoon of July 12 was spent in an inspection of the cereal experiments of the Minnesota station. On July 13 those in attendance at the conference visited the Minnesota Grain Inspection Department, the Minneapolis Grain Exchange, the laboratory and baking departments of the Pillsbury Flour Co. and the Washburn-Crosby Co., the experimental mill of the latter company, and the malting plant of the North Star Malting Co.

At the business session, the following executive committee was elected for the ensuing year: R. W. Thatcher of the University of Minnesota, *chairman;* Charles E. Chambliss of the U. S. Department of Agriculture, *secretary;* and M. A. Carleton of the U. S. Department of Agriculture, L. A. Fitz of the Kansas station, and Frank J. Seidl of the Gould Grain Co., Minneapolis.

Conference of Western Agronomic Workers.

A 3-day conference of western agronomic workers was held at the Utah Agricultural College, Logan, Utah, on July 18–20, 1916. Morning and afternoon sessions were held each day, making six sessions in all. Representatives were present from 7 states. The total attendance was nearly 70 and the average attendance was 45.

The morning session on Tuesday, July 18, was devoted to a discussion of the relation between agronomic teaching, extension, and experimentation. This discussion was led by Dr. E. D. Ball, of Utah, and Prof. E. G. Schafer, of Washington. The afternoon session was devoted to methods of teaching and laboratory work in agronomy, the discussion being led by Prof. Alfred Atkinson, of Montana.

On Wednesday, July 19, both sessions were devoted to methods of experimentation. The general discussion was opened by Dr. F. S. Harris, of Utah, after which assigned leaders discussed the special topics of soils, irrigation, drainage, dry farming, crops, and farm management. On Thursday, the third day of the conference, the morning session was devoted to 10-minute summaries of important experiments being conducted at various stations and substations in the regions covered. The discussion was led by Mr. C. R. Ball, U. S. Department of Agriculture. The final session was devoted to extension work in agronomy, the discussion being led by Dr. J. W. Gilmore, of California.

Arrangements for the conference were in the hands of a committee consisting of Dr. Frank S. Harris, Mr. C. R. Ball, and Prof. J. W. Gilmore. The invitation of the Washington Agricultural College and Idaho University to hold the second conference at Pullman-Moscow in 1917 was accepted. The arrangements for the next conference were left to a committee consisting of Prof. E. G. Schafer of Washington, Prof. P. P. Peterson of Idaho, and Mr. C. R. Ball of the U. S. Department of Agriculture.

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SOME PROBLEMS IN AGRONOMY.

CARLETON R. BALL,

U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

(Presidential address before the American Society of Agronomy, November 13, 1916.)

Members of three organizations are gathered here tonight. One of these,[1] and the oldest, was founded in 1880, to promote general agricultural science. The second,[2] only nine years old, and which the speaker has the honor to represent, was organized in 1908, to promote particularly the study of farm crops and the soils on which they grow. It is thus one of the newest of the specialized societies. The third[3] is an association of those engaged in applying to the business of modern farming the pertinent discoveries of agricultural science and economics.

In a good sense, these three societies typify the viewpoint of scientific workers in three overlapping periods, which may be called, without prejudice, the periods of yesterday, today, and tomorrow. Yesterday,—when science itself was broad and unspecialized and education built on broader and more solid foundations, developing men with an inspiring breadth of knowledge and with capacity for wise and efficient leadership. Today,—when specialized education and specialized production are the rule, developing men with quickened insight into old problems and keen appreciation of the myriad new problems of the day. It fosters extensive experiment and intense research. Tomorrow,—when the obligation to labor for humanity shall be universally acknowledged, and when "Truth for truth's sake" shall be held an ideal somewhat less noble than "Truth for man's sake."

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[1] The Society for the Promotion of Agricultural Science.

[2] The American Society of Agronomy.

[3] The American Farm-Management Association.

But what of the problems of agronomy? Every year there comes out from our colleges of agriculture and related institutions a small army of young men, and some young women, eager to devote their lives to the solution of the riddles of science. What opportunities lie before them? Have all the great discoveries been made? Are all the problems solved or in the process of being solved? Are all the visible and attractive avenues of investigation preempted by the graduates of previous years? In one form or another this question comes before us in the day of matriculation and of graduation. What shall be our answer?

There is but one answer to this question. The best lies yet before. It is the wise answer because it is the truth. This is unquestionably the golden age of scientific research and discovery. To the young it may seem that every field is full, that every claim is staked. From every imaginable angle and upon every conceivable object the searchlight of science is pouring its flood of light. This may seem especially true in agronomy, which is the campus and the laboratory, the meeting ground and the workshop, of so many sciences. Agronomists, agrostologists, botanists, chemists, ecologists, edaphists, geneticists, pathologists, physicists, physiologists, and solologists,—technical workers from every nation under heaven,—are engaged in studying the problems of the crop and the soil. But if the field seems occupied, it is because our vision is so limited. We see but dimly the objects close at hand, and see the distant objects not at all.

When we climb upward from a narrow valley to a lofty mountain peak, the circle of our landscape ever widens! First of all, the features of the valley floor become discernible, then new salients of the range we climb, and finally there opens out before our vision a vista of peaks and ranges, stretching away to the far horizon. The life of scientific endeavor is like that. The achievement of the moment is but the threshold of the broader view, and the murmur of the stronger call in the hour about to strike. There are no blind alleys, no cul-de-sacs, in the fields of science. Every highway has its scores of lateral roads, every road its hundred diverging paths, every path its thousand onward-leading trails, and every trail, however dim, leads at last into the open spaces where abides new truth.

What are the problems of agronomy? They are not alone the problems of the crop and the soil and the environments of both. They are, as well, (1) the problems of the student and his training; (2) the problems of the worker and his personality in relation to his fellow workers; (3) the problems of formulating new plans and devising effective methods of procedure; (4) the problems of keeping complete, accurate, and interpreted records; and finally (5), the problems of keenness and accuracy of observation and sanity of interpretation. These last are all problems of the personality, of the human equation. Let us consider them for a moment.

Problems of the Worker.

Training.

Before another organization the writer once had occasion to illustrate different methods of training students for the science and art of agronomy. Since this illustration has never been published, it may be proper to use it briefly here. Attention was attracted to the subject by the difference in attainment and attitude observable in the students from different colleges. A study of their curricula, with regard to a general groundwork of science and superstructure of specialization, revealed differences which fall into three classes. These classes may be represented by the three geometrical figures, (1) the pyramid, (2) the parallelogram vertically placed, and (3) the inverted pyramid.

The pyramid represents the course in which the freshman and sophomore years are devoted largely to fundamental sciences, as physics, chemistry, biology, and botany, with mathematics and language. In the junior and senior years increasing specialization is permitted. The parallelogram represents the curriculum in which there is a fair foundation of general science, but some specialization is allowed even in the freshman year. The inverted pyramid represents the course in which specialization is the order of the day from the very beginning of the course, and some of the fundamentals appear only near the end of the four-year period, as if in a belated endeavor to supply a previously unrecognized lack.

Consider now the three figures from the standpoint of the architect! Let the broken lines on each represent the superstructure that may be safely added in the years after college. We note that only the first gives an adequate foundation for future building. The second can be built upon, but the structure is narrow and unless the foundation be widened and deepened, must remain narrow for all time. The third scarcely can be built upon at all. A new and safe foundation must first be laid. To adjust properly the problem of training while in college is to take the first step in the attack on the problems that come after.

Personality.

The problems of personality are, of course, as diverse as the men involved. They have to do with scientific men in their relations to their constituents, their fellow scientists, and their employers; in their relations with their subordinates, their coordinates, and their superordinates, sometimes called their superiors. Naturally these questions are as vital as any that arise.

Should a man seek and accept a position in which he intends to remain only as long as it takes to find a better? Does a man enhance or diminish his scientific standing by associating with himself a corps of strong men, some of whom may equal or even surpass him in ability? Will a young man develop most rapidly by publishing independently or jointly with his superordinates? Should a man publish frequently on a continuing experiment, making data available to others but permitting the accusation of rushing into print? Should he publish only after a considerable body of data has accumulated, keeping it long inaccessible to others and laying himself open to the charge of laziness or neglect? Does the organizing and administration of a unit containing many good workers guarantee a man's scientific standing or must he himself conduct experiments and publish results? What should he do if his time and ability do not permit both? Should a man's name appear as author or senior author of a publication if he has neither done the experimental work nor written the results? What is the object of unfavorable criticism, to champion truth, or to display superior knowledge? If a fellow scientist must be criticised unfavorably, how should it be done? Will a kindly personal letter or a public review in a professional journal accomplish the most good?

Wrongly answered, these and similar questions cause controversy, provoke ill feeling, arouse resentment, destroy respect, induce disloyalty, diminish reputation, retard investigation, curtail output, discourage originality, and outrage the sense of justice. Rightly answered, they promote harmony, build friendships, induce loyalty, develop respect, enhance reputation, encourage industry, warrant sacrifice, and increase knowledge. Ethically these questions may not be evaded; economically their right solution pays high dividends on the investment.

Cooperation.

Cooperation is one of the slogans of the day. Rapidly it is advancing from the realm of things hoped for to the realm of things realized. The experience of working in partnership with another is excellent discipline for the agronomist. It keeps him out of ruts, restrains him from haste, inaccuracy, and intolerance, broadens his vision, and develops his judgment. All of this is good both for the man and the science he serves. We see abundant cooperation between individuals, rather frequent cooperation between subordinate administrative units, and occasional cooperation between large administrative organizations. In general the work has been planned wisely and carried on without friction, and has produced results satisfactory to both parties, with a saving of both men and money.

Our Union is composed of forty-eight separate entities, with several outlying territories. In each of these, experiment, and usually research, is being conducted. Problems do not cease at State boundaries. Is it too much to hope that soon we shall see cooperation between neighboring States in solving problems common to both? No State, however well endowed, has yet had funds and workers enough to permit effective attack on all its pressing problems. Why not by agreement divide the common problems, each taking a share, or else conduct identical and simultaneous experiments, the one duplicating the other, and then unite in joint publication of the results? Already we see signs of such a millennium. An eastern State has recently published to its citizens a bulletin written by the workers in an adjoining State, while two western States have united in a joint publication.

States having their stations or substations not too distant from each other and similarly situated, as Idaho and Washington, or Colorado and Wyoming, or Kansas and Nebraska, might profitably conduct experiments in duplicate or divide the field. What statesmen among present-day agronomists will be the pioneers in a movement to put such practical cooperation into effect?

Procedure.

In planning an experiment the first question is whether the plan proposed will serve to solve the problem involved. There is a constant evolution of procedure in experimental work in the light of increasing knowledge. Two familiar instances will suffice for illustration.

One is the case of the ordinary plot experiment to determine the comparative yielding power of different varieties. For a long generation it has been considered that a single plot of each variety was sufficient if check plots of a standard variety were inserted at more or less frequent intervals. The actual yield obtained from a plot of a variety was corrected by factors including the average yields of all checks and the distance of the varietal plot from the nearest check. Grave doubts arose finally as to whether this method produced dependable results. A study of the effect of various degrees of replication in reducing experimental error was pursued at home and abroad. As a result, most experiments of this kind are now replicated from two to five times. In the next ten years the number of replications held necessary may very probably increase to as many as eight or ten. It is even possible that presently we may be replicating twenty or thirty or even fifty times in single short rows and not using plots at all for this purpose.

Turning now to the early experiments in the effect of crop rotations, we find that until recently but a single plot was devoted to each rotation. This single plot would carry one phase of the rotation each year until all phases had appeared in sequence. After much expenditure of time and money it was gradually realized that a single plot can scarcely solve the problems of a four-year rotation. Now, no experimenter would seriously think of starting such experiments with fewer plots than there are phases in the rotation to be studied. Presently we may insist that rotation plots also shall be replicated. Many omit the replication of experimental plots because of the increased consumption of land, labor, and funds. But gradually the realization grows that the true test of accomplishment is not how much but how well. What does it profit an experimenter if he save his land and labor and lose his result? In homely phrase, it is better not to learn so much, than to learn so much that is not so!

Records and Interpretation.

The historical aspects of experimentation and research are important. They contribute to an appreciation of the gradual development of scientific knowledge. Eventually our colleges of science will teach the history of science, regarding it as a needed foundation. From the practical standpoint, full and complete records are necessary to uninterrupted progress. Men come and go. Too often their going means the breaking of the continuity of experiments, because only fragmentary records of procedure and results are left. Usually those who are making history have little time or inclination to write it, at least during their days of active work. But the records of experimentation and those of human history are not directly comparable. With experiments, the current records are of vital importance to the conclusion. These records can be made only by the man who conducts and interprets the experiment, none other.

In the judgment of the writer, one practice of the United States Department of Agriculture has been of enormous value to the coordination, continuity, and conclusion of experimental work in the Department. I refer to the project system. This system requires the submission of a project outline and its approval before work is begun, and an annual report of progress thereafter. All experimenters are thereby compelled to justify their plans and also to take account of stock at regular intervals.

To these requirements should be added a third, and it is so added in many offices. This is a full annual report of the procedure, results, and interpretation of the experiment to date. Only by such means can be prevented an enormous loss of headway with each change of personnel in the leadership of projects. Such records not only encourage frequent publication, but also obviate great loss of time in preparing data when publication becomes desirable. This method of complete and continuous record requires added clerical labor, but is acknowledged to increase the sum total of effective experiment in the end.

Problems of the Soil and Plant.[4]

Turning now from the thought of men and methods, let us survey some problems presented by the soil, the plant, and the environment surrounding both. Everywhere we see the continuing processes of birth, growth, metamorphosis, decay, and final disappearance. This is as true of the soils, so-called dead, as of the living plants. Everywhere also are the evidences of reaction and interaction. Soil reacts on soil, plant on plant, each on the other, and other environmental factors on both. It is the great complex of nature. What is our attitude toward it?

The child sees an object new and strange. His first question always runs, "What is it?"; his next, "What is it for?"; and finally, "How does it work?" Name, structure, and function, these things he wants to know and in this order. We are all as children, querulous before the riddles of the universe. "What is it?" we ask. "What are the wonders of its structure and the mysteries of its functions?" "Why these particular reactions to the environing factors?" "What?" "How?" and "Why?" are the eternal queries of nature, and the greatest of these is "Why?"

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[4] The writer gratefully acknowledges many helpful suggestions received from his associates in the Bureau of Soils and the Bureau of Plant Industry.

Like children, too, we often fail to discover many wonderful things through lack of trained vision. To look at what comes before our eyes, to see what we look at, to think on what we see, to prove and record what we think, and to make available to others that which we record, if worthy, these are the links in the chain of scientific obligation.

The solution of the problems of modern research lies in an increasing refinement of method. The experimenter must turn from gross aspect to minute detail. The official investigator must become the sympathetic companion. The secrets of nature are not taken by surprise. There are no third degree methods in agronomy. Who walks in her ways must tread softly, and carry no stick at all, unless it be a metric measure. Inspiration may point the problems, but patience and perspiration must work out their solution.

Said Froebel, "Come, let us live with our children." Says Research, "Come, let us live with nature." "To him, who in the love of nature, holds communion with her visible forms, she speaks a various language" said Bryant in his immortal Thanatopsis.

It is not enough to live with the soil area, we must know intimately the soil grain. It is not enough to live with the replicated plot, we must live with the individual plant, even with the unfolding leaf, the opening flower, the ripening fruit. We must know not only whence it came, but what it really is; not only how it looks, but how it is made; not alone what it does, but why it does so.

Longfellow, in "The Song of Hiawatha," tells us:

"Then the little Hiawatha
Learned of every bird its language,
Learned their names and all their secrets,
How they built their nests in summer,
Where they hid themselves in winter;
Talked with them whene'er he met them,
Called them 'Hiawatha's Chickens.'

. . . .

"Of all beasts he learned the language,
Learned their names and all their secrets,
How the beavers built their lodges,
Where the squirrels hid their acorns,
How the reindeer ran so swiftly,
Why the rabbit was so timid,
Talked with them whene'er he met them,
Called them 'Hiawatha's Brothers.'"

Hiawatha evidently was a zoologist, but only because of the recognized curriculum for a man and warrior in his day, when agronomy was woman's work. To the agronomist of the present the same type of education is necessary. So must workers agronomic glean the fruitful fields of science:

> Learn of every soil its secret,
>   What its origin and structure,
> What its name and composition,
>   How to use and still improve it;
> Learn of every plant its language,
>   Know its structure and its functions,
> Prove its multifold reactions,
>   Strive to breed and make it better.

Soil Problems.

The problems of the soil are fundamental, numerous, and diverse. They lie in the domains of geology, chemistry, physics, and ecology, and deal with origin, composition, and use. The goal of hosts of persevering workers, they are now in varying degrees of elucidation. In the realm of survey and classification, the last word has not yet been said on the questions of origin, composition, structure, transformation, translocation, and description of soils.

What is the relative importance of parent rock, climate, vegetation, and gravity in determining soil characteristics? What is the significance of soil composition in relation to crop yields? How may chemical analyses be interpreted in terms of soil evolution? What is the relation of soil condition or progressive soil development to natural plant rotation? What is the relative importance of structure and composition in effect on crop yields? How may be determined the suitability of a given soil type to the production of specific crops? Which are the major and which the minor factors in soil classification? What shall be the basis of a rational soil nomenclature?

How may soil blowing be prevented? Is there any other temporary relief than surface tillage? What permanent measures are best, shelter belts and windbreaks or the addition of manure and straw?

On the chemical side are many questions. What are the nature and influence of the soil solution? What are the functions and effects of fertilizers, including the effect of different carriers, the action of catalytic fertilizers, and the ratio of fertilizing elements best suited under varying conditions? What is the nature and what are the causes of soil acidity and what are the chemical, physical, and biological effects of lime? What is the nature of humus, and of soil organic matter in general? What are the physical and biological effects of adding organic matter to soils, and what are the processes of their decomposition? What are the nature, distribution, and influence of the organic constituents of the soil? What are the nature and prevalence of toxic excretions and toxic residues and what is their influence on crop rotation? What are the origin and nature of different alkalis and how may they be neutralized or dispersed? What is the relation of soil conditions to the prevalence of certain plant diseases? How are soil conditions influenced by natural and artificial drainage?

Plant Problems.

In the field of plant culture the questions which confront us are equally abundant and complex. Here, too, they arise in the domains of other sciences, as botany, physiology, chemistry, and ecology, so-called. Fundamental to any refinement of research on crop plants and plant varieties is a study of both gross and minute plant characters and a classification of crop varieties based on such study. To determine, record, and publish the performance of so-called varieties is but vexation, if few or none can tell what plant has been in hand. In a neighboring State the same name may cover an entirely different variety, while perhaps in the other end of our own State the same variety is grown all unwittingly under an entirely different name. How can varietal adaptations be determined under these conditions? The writer and his assistant have amassed in the last four years, and are now studying, a collection of nearly ten thousand herbarium specimens in an attempt to classify the wheats of western America alone. This is but the beginning of what must finally be done in this enormous enterprise.

When once begins the study of the detailed character of a plant, questions arise in endless procession. What is the function of pubescence? Of what value are the awns in cereals and other grasses? Do they act merely as buffers to prevent shattering under wind action, do they function in transpiration and the ripening of the kernel, or are they remnants of organs designed to protect ancestral plants from extermination by grazing animals? Why does the potato store starch in a subterranean stem, the sweet potato in a root, and the cereal in its seeds? What are the phenomena of pollination in different crops? What percentage of the plants of so-called self-fertilized crops are commonly cross-fertilized and under what conditions? Why is wheat so commonly open-pollinated in dry regions? How far are viable pollen grains carried? Why do sorghum flowers open in darkness? What seeds and plants require an annual rest period and why? Is tillering in cereals a desirable character? Is it possessed equally by all varieties of a crop, and is it heritable? What is the function of pigment? Why does sap in spring flow upward?

Are there any fundamental differences between spring and winter varieties, so-called? What underlies cold resistance? Is it habit of growth, or structure, or water content, or chemical composition? What are the phenomena of drought resistance? How much of it is evasion due to earliness or other causes, how much escape through devices not yet known, and how much resistance by means of special adaptations? Why is milo immune to sorghum smuts? Does disease resistance reside in thickened epidermis, or guarded stomata, or chemical reaction? What are the factors governing transpiration under varying conditions? Why are all cereals annuals? Is the wheat crop sown too deeply? How can dwarf habit be induced and how far is it desirable in crops? How much does our weed crop cost the country annually? How control such weeds as tumbling mustard, tumbleweed, and Russian thistle? Should a nation-wide campaign for weed eradication be inaugurated? How important are the characters of root systems? Do they differ in different varieties of the same crop? Why do some seeds germinate at low temperatures and others only with high temperatures? Why does one crop require two or three times as much water as another to produce a pound of dry matter? What is the relation of available heat or light units to photosynthesis? What determines the height of a plant?

But why weary the mind with long enumeration? These are but samples of the greater fabric and many more occur to each of you. Agronomy asks only that every man shall do his bit, shall follow on at least one quest. From the unrelated fragments of knowledge thus brought forth shall slowly rise the massive and enduring edifice of agronomic truth.

SOME EFFECTS OF LEGUMES ON ASSOCIATED NONLEGUMES.[1]

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Bureau of Plant Industry, U. S. Department of Agriculture.

Introduction.

The effect of leguminous plants on the protein content of nonleguminous plants growing in mixture with them has been studied by several investigators during recent years. The results of these investigations, together with bibliographies of the literature bearing on this problem, have been published in various bulletins and reports.[2]

An investigation of some of the effects of leguminous plants on nonleguminous plants growing in mixture with them was conducted at New London, Ohio, during 1912, 1913, 1914, and 1915.[3] Clover (*Trifolium pratense* and *T. repens*) was used as the leguminous plant; timothy (*Phleum pratense*), redtop (*Agrostis alba*), and Kentucky bluegrass (*Poa pratensis*) were grown alone and in mixture with the clover in different plots. The plots were cut at intervals with a lawn mower. At different times samples of the lawn clippings were collected, in order to determine the relative nitrogen content of grass grown alone and in mixture with clover and for the purpose of making a study of the comparative growth in length of the leaves

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[1] Received for publication May 10, 1916.

[2] Lyon, T. L., and Bizzell, J. A. A Heretofore Unnoted Benefit from the Growth of Legumes. N. Y. (Cornell Univ.) Agr. Expt. Sta. Bul. 294. 1911.

Lipman, J. G. The Associative Growth of Legumes and Nonlegumes. N. J. Agr. Expt. Sta. Bul. 253. 1912.

Westgate, J. M., and Oakley, R. A. Percentage of Protein in Nonlegumes and Legumes when Grown Alone and in Association in Field Mixtures. Jour. Amer. Soc. Agron., v. 6, no. 4-5, pp. 210-215. 1914.

Ellett, W. B., Hill, H. H., and Harris, W. G. The Effect of Association of Legumes and Nonlegumes. Va. Agr. Expt. Sta. Tech. Bul. 1. 1915.

[3] The experiments described in this publication were performed on the Timothy Breeding Station at New London, Ohio, which is conducted cooperatively by the U. S. Department of Agriculture and the Ohio Agricultural Experiment Station. A large part of the work of collecting lawn clippings and separating samples for chemical analyses was done by Mr. S. R. Heffron, who was employed as assistant on the station at New London. The determinations of the percentage of protein in the various samples were made by Dr. G. L. Bidwell, of the Bureau of Chemistry, U. S. Department of Agriculture.

when the grass was grown alone and with clover. The effect of the clover on the relative number of green leaves on the grass growing in mixture with it was also observed.

All the data presented in this paper refer to results obtained with young grass and not with mature plants. The parts of the grass used for measurements and analyses were the green leaves, which represented the new growth made during a period of one or two weeks immediately before the samples were collected.

It has been found that as grass approaches maturity, the percentage of protein decreases.[4] The relatively high percentage of protein in nearly all analyses given in this report may be attributed to the immature condition of the grass. The samples collected from the square-rod lawn plot of timothy on June 17, 1915, became somewhat discolored when drying, which may account for the relatively low percentage of protein which they contain.

Several applications of ammonium nitrate were made on duplicate plots of timothy for the purpose of comparing the effect of clover with the effect of a nitrogenous fertilizer on grass. It has been repeatedly demonstrated that the growth of grass responds quickly to the application of fertilizers containing soluble forms of nitrogen. Several investigators have also found that the use of nitrogenous fertilizers causes an increase in the percentage of protein in grass.[5]

The roots of the clover plants growing in the various plots used in these experiments were examined on several different dates. Nodules were always found on the roots.

Plots Used in the Experiment.

The samples were collected from two sets of plots of timothy and from one set of plots each of redtop and Kentucky bluegrass.

A square-rod plot of timothy was seeded in September, 1912. In the spring of 1913, white clover was sown on half of the plot; in the spring of 1914 more clover seed was added. A comparatively dense stand of white clover was growing during 1914 and 1915 on the part of this plot where it was seeded. The half of the plot where the timothy was growing alone was subdivided into two parts, as was also the half of the plot where clover was sown. This plot is shown in Plate XVI, figure 1.

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[4] Jordan, W. H., Maine State Coll. Agr. Rpt. 1879, p. 39; Richardson, Clifford, U. S. Dept. Agr. Rpt. 1883, p. 231; Morse, F. W., N. H. Agr. Expt. Sta. Rpt. 1893, p. 138.

[5] Woods, C. D. Effect of Nitrogenous Fertilizers upon the Percentage of Protein in Grasses and Grains. Conn. (Storrs) Agr. Expt. Sta. Rpt. 1892, pp. 60–66.

Lipman, J. G., and Blair, A. W. Field Experiments on the Availability of Nitrogenous Fertilizers. N. J. Agr. Expt. Sta. Bul. 260. 1913.

A field of timothy was seeded on October 4, 1913. In the spring of 1914, six areas in this field, each 1 rod square, were marked off. On two of these square-rod plots, no clover was sown nor fertilizer applied. On two other square-rod areas, red clover was sown; additional clover seed was also sown in the spring of 1915. There was a uniform stand of red clover in these plots in both 1914 and 1915. No fertilizer was applied on either plot. On the third set of duplicate plots, an application of 4 ounces of ammonium nitrate was made on each of the following dates in 1914: September 5; September 17; October 1; and October 15. This was equivalent to a total application of 160 pounds of ammonium nitrate per acre in 1914. Four ounces of ammonium nitrate per plot were also applied on each of the following dates in 1915: May 7; June 19; July 23; and August 21.

On September 28, 1913, four plots of 1 square rod each were seeded, one to redtop, one to redtop and white clover, one to Kentucky bluegrass, and one to Kentucky bluegrass and white clover. There was a good stand of clover on the plots where it was sown, in both 1914 and 1915. Some volunteer clover plants developed in the other plots, but were removed soon after they appeared.

EFFECT OF CLOVER ON THE PERCENTAGE OF PROTEIN IN GRASS.

In obtaining the samples for the analyses presented in Table 1, only those grass blades which were entirely green were taken; all leaves and stems of clover or weeds, all grass stems, and all dry or partially dry grass blades were discarded. The percentages of protein given in these tables are those contained in the water-free material, calculated by multiplying the percentage of nitrogen by 6.25.

The percentages of protein in samples of green grass blades taken from the portions of the square-rod lawn plot where the timothy was grown alone and also from where it was grown in mixture with white clover are given in the first section of Table 1. The samples were collected at two different times in 1914 and on four dates in 1915.

The percentages of protein in the green grass blades from the field of timothy where it was growing alone, where it was growing in mixture with red clover, and where it was fertilized with ammonium nitrate, are given in the second section of Table 1. As the first application of ammonium nitrate was made on September 5,

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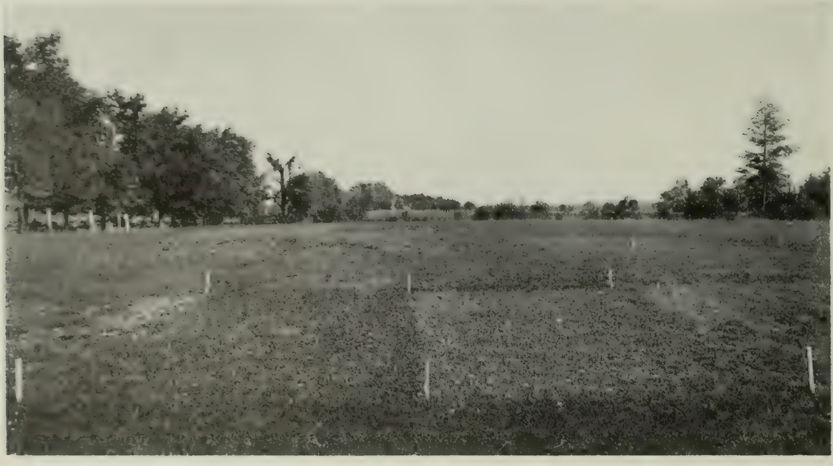

FIG. 1. Square-rod lawn plot of timothy used in the experiment. On the left half of the plot white clover is growing in mixture with timothy, while on the right half timothy is growing alone.

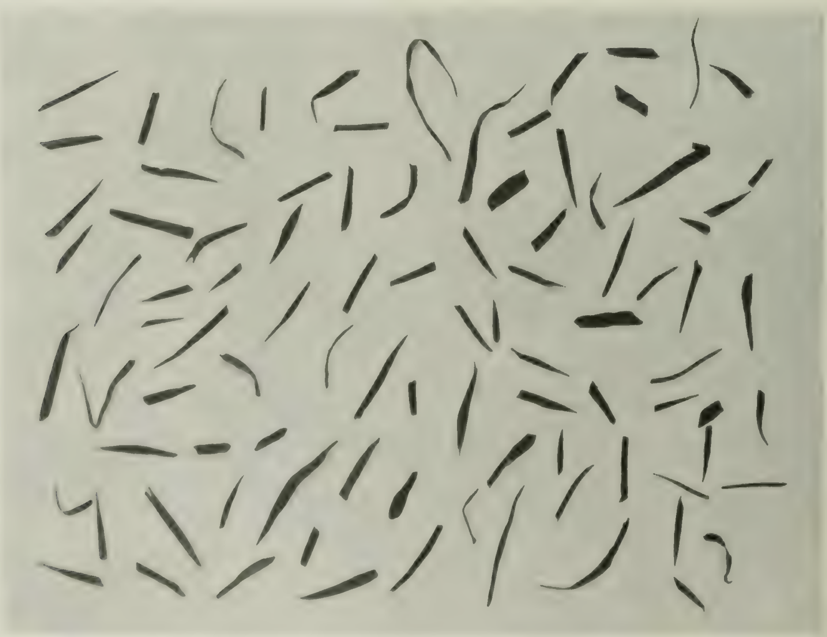

FIG. 2. Green grass blades from lawn clippings from the plot where timothy was grown in mixture with red clover.

1914, two days after the first samples were collected, the percentage of protein contained in the grass samples collected on September 3 is not included in the average percentage of the samples from that portion of the plot.

The percentages of protein contained in green blades collected on eight different dates in 1914 and 1915 from the plot of redtop grown alone and from the plot of redtop grown in mixture with white clover are given in the third section of Table 1. Similar determinations for Kentucky bluegrass grown alone and in mixture with white clover are given in the fourth section of this table. Duplicate samples of both redtop and Kentucky bluegrass were obtained at each of the first three dates, and a single sample at each of the five later dates.

The analyses presented in Table 1 show that, in the samples collected on each date, the average percentage of protein in timothy

TABLE 1.—*Percentages of protein on different dates in 1914 and 1915 in timothy, redtop, and Kentucky bluegrass clippings when grown alone and in mixture with either white or red clover.*

TIMOTHY FROM SQUARE-ROD LAWN PLOT.

Date.	Grass alone.			In mixture with clover[a].			Fertilized with ammonium nitrate.		
	Plot 1.	Plot 2.	Ave.	Plot 1.	Plot 2.	Ave.	Plot 1.	Plot 2.	Average.
1914									
Sept. 3	19.19	19.00	19.09	24.30	23.49	23.89			
Sept. 17	21.23	21.04	21.13	25.32	25.83	25.57			
1915									
May 5	19.24	18.90	19.07	23.01	22.21	22.61			
June 17	....	....	11.42	....	....	15.33			
July 22	....	....	19.36	....	....	19.62			
July 29	....	....	20.07	....	....	23.98			
Average	......	......	18.36	......	......	21.83			

TIMOTHY FROM FIELD PLOTS.

Date.	Grass alone.			In mixture with clover[a].			Fertilized with ammonium nitrate.		
	Plot 1.	Plot 2.	Ave.	Plot 1.	Plot 2.	Ave.	Plot 1.	Plot 2.	Average.
1914									
Sept. 3	21.26	24.66	22.96	22.44	24.54	23.49	23.26	21.29	22.27
Sept. 17	23.04	25.00	24.02	25.70	25.35	25.52	28.14	26.52	27.33
Oct. 11	21.91	22.49	22.20	24.47	23.25	23.86	27.63	28.08	27.85
Oct. 15	23.16	25.49	24.32	26.76	26.41	26.58	32.51	32.67	32.59
Nov. 12	17.56	18.87	18.21	19.37	19.12	19.24	22.29	23.70	22.99
1915									
May 5	18.00	18.82	18.41	20.11	20.67	20.39	21.23	21.63	21.43
June 17	18.96	19.89	19.47	22.90	21.38	22.14	24.04	23.61	23.82
July 22	18.58	17.68	18.13	19.03	19.13	19.08	18.84	18.40	18.62
Nov. 18	16.91	17.67	17.29	18.34	19.43	18.88	18.99	18.29	18.64
Average	......	......	20.55	......	......	22.13	......	......	24.15

[a] White clover with timothy in lawn plots and with redtop and Kentucky bluegrass; red clover with timothy in field plots.

Table I.—*Percentages of protein on different dates, etc.—Continued.*

REDTOP.

Date.	Grass alone.			In mixture with clover[a].			Fertilized with ammonium nitrate.		
	Plot 1.	Plot 2.	Ave.	Plot 1.	Plot 2.	Ave.	Plot 1.	Plot 2.	Average.
1914									
Sept. 3..........	30.20	30.05	30.12	30.50	31.10	30.80			
Sept. 17..........	29.68	28.39	28.53	27.90	27.62	27.76			
Oct. 15..........	24.63	24.37	24.50	26.62	26.33	26.47			
Nov. 19..........	....	....	17.81	....	....	19.21			
1915									
July 29..........	....	....	18.87	....	....	24.69			
Aug. 21..........	....	....	28.40	....	....	31.70			
Sept. 28..........	....	....	23.16	....	....	27.00			
Nov. 18..........	....	....	17.61	....	....	19.30			
Average.........	......	......	23.62	....	....	25.86			

KENTUCKY BLUEGRASS.

1914									
Sept. 3..........	28.39	28.33	28.36	30.83	30.50	30.66			
Sept. 17..........	27.71	28.13	27.92	29.20	30.96	30.08			
Oct. 15..........	27.15	26.98	27.06	29.03	29.63	29.33			
Nov. 19..........	....	....	21.22	....	....	23.85			
1915									
July 29..........	....	....	10.93	....	....	18.16			
Aug. 21..........	....	....	24.93	....	....	31.85			
Sept. 28..........	....	....	19.77	....	....	22.41			
Nov. 18..........	....	....	18.37	....	....	21.51			
Average.........	......	......	22.32	......	......	25.90			

which was grown in mixture with clover is higher than in timothy from the corresponding plot where no clover was grown. On each of the dates when grass blades were collected from the plots where ammonium nitrate had been applied, there was an increase in the percentage of protein in the grass from these plots over that contained in the grass from the plots where the grass was grown alone and no fertilizer applied; the increase in protein content was considerably greater, in most instances, when ammonium nitrate was applied than when clover was grown in mixture with the timothy. The effect of the nitrogenous fertilizer upon the chemical composition of the grass was quite evident in the analyses of the samples collected on September 17, 1914, twelve days after the first application of fertilizer was made.

In the samples collected on September 17, 1914, the percentage of protein was somewhat greater in redtop grown alone than in the grass grown in mixture with clover. In all samples collected on seven other dates in 1914 and 1915, however, the redtop grown in mixture with white clover contained a greater percentage of protein than the redtop grown alone. The percentage of protein is greater in all samples from the plot where Kentucky bluegrass was grown in mixture with clover than in the corresponding samples from the plot where the grass was growing alone.

EFFECT OF CLOVER ON GROWTH OF GRASS LEAVES.

The effect of the clover on the growth of the grass leaves was determined by measuring the length of the green grass blades, after obtaining the samples according to the method described below.

At intervals during the growing season of 1914 and 1915, the plots were cut with a lawn mower. The lawn clippings were collected by means of a canvas attached to the mower. Previous to July 9, 1914, when the samples were collected from the square-rod plot of timothy all of the clippings were placed on a table and a number of green grass blades, usually from 75 to 100, were taken promiscuously and measured. On and after July 9, 1914, when taking the samples for measurement from all of the plots, the entire quantity of lawn clippings collected was distributed uniformly over a narrow strip across the surface of a table. A typical portion of the clippings was taken, and the remainder discarded. The same process was then repeated once or twice, or until a suitable sample was obtained. In 1914 all green grass blades in the final sample which exceeded 0.3 inch in length were measured, while all shorter portions of green grass blades and also all brown or partially brown grass blades were discarded. In 1915, all green portions of blades less than 0.5 inch in length were discarded. The samples obtained in this way were evidently quite nearly representative of the entire number of grass clippings collected.

Results of these measurements for the samples of lawn clippings collected from the lawn plot of timothy are presented in Table 2. The east half of the plot, where no clover seed had been sown, was separated into duplicate subdivisions. The west half of the plot was also divided into two parts; white clover seed had been sown on each of the two latter subdivisions.

The length of the timothy grass blades collected in lawn clippings from the timothy field was measured on October 15, 1914, and on August 11, August 21, and November 18, 1915. The results are presented in the second portion of Table 2. In this table the length of the green grass blades from 2 square rods on which ammonium nitrate had been applied was compared with the length of the grass blades from the portions of the plot where timothy was grown in mixture with red clover and where it was grown alone, without fertilizer. Representative clippings from the three plots are shown in Plate XVI, figure 2, and in Plate XVII.

TABLE 2.—*Average length in inches of timothy leaves on various dates, when grown alone, when grown in mixture with clover, and when fertilized with ammonium nitrate.*

TIMOTHY FROM SQUARE-ROD LAWN PLOT.

Date.	Grass alone.					In mixture with clover.					Fertilized with ammonium nitrate.				
	Plot 1.		Plot 2.		Average for both plots.	Plot 1.		Plot 2.		Average for both plots.	Plot 1.		Plot 2.		Average for both plots.
	No. of leaves.	Average length.	No. of leaves.	Average length.		No. of leaves.	Average length.	No. of leaves.	Average length.		No. of leaves.	Average length.	No. of leaves.	Average length.	
1914															
May 14	93	0.98	90	1.01	0.99	75	1.28	93	1.24	1.26					
May 21	124	.90	98	1.06	.98	77	1.22	113	1.07	1.14					
May 28	92	.89	72	1.06	.97	53	1.38	86	1.20	1.29					
June 4	92	1.03	66	1.16	1.09	68	1.24	74	1.35	1.29					
June 11	59	.90	50	.78	.84	104	1.03	57	1.05	1.04					
June 25	61	1.00	62	1.14	1.07	56	1.19	50	1.18	1.18					
July 9	94	.81	127	1.01	.91	64	1.15	78	1.10	1.12					
Sept. 3	77	.85	55	.88	.86	95	.93	82	.96	.94					
Sept. 17	79	.78	66	.83	.80	69	1.00	63	1.15	1.07					
Average	...	....	...	....	.94	...	....	...	....	1.14					
TIMOTHY FROM FIELD.															
Oct. 15	68	.76	71	.62	.69	49	1.08	43	.89	.98	47	1.13	57	0.89	1.01
1915															
Aug. 11	55	1.32	56	1.48	1.40	54	1.67	68	1.79	1.73	57	1.76	60	1.82	1.79
Aug. 21	34	1.15	48	1.28	1.21	40	1.24	67	1.37	1.30	52	1.17	29	1.20	1.18
Nov. 18	64	.85	56	.84	.84	60	.92	50	.94	.93	65	.85	50	.87	.86
Average	...	....	...	....	1.03	...	....	...	....	1.23	...	....	...	....	1.21

The average lengths of the green grass blades in the lawn grass clippings collected on November 23, 1914 and on August 21, September 28, and November 18, 1915, from the plot of redtop grown alone and from the plot of redtop grown in mixture with clover, are given in Table 3. The lengths of the green blades collected on these dates in 1914 and 1915 from the plot of Kentucky bluegrass grown alone and in mixture with white clover are also given in Table 3.

The results presented in Tables 2 and 3 show that in every instance when the length of the leaf blades from grass grown alone is compared with the length of blades from grass grown in mixture with clover, the grass blades are longer in the samples taken from plots where clover was grown.

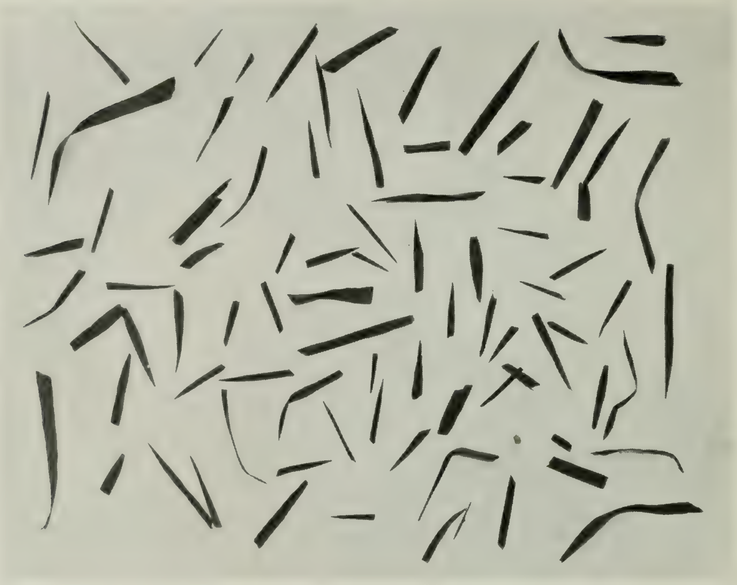

FIG. 1. Green grass blades from lawn clippings from plot where timothy was grown alone, without fertilizer.

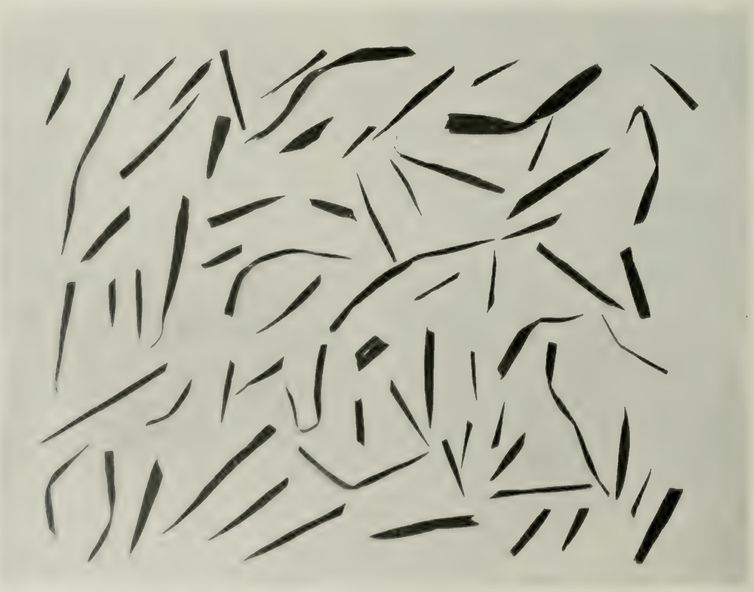

FIG. 2. Green grass blades from lawn clippings from plot where timothy was grown alone and was fertilized with ammonium nitrate.

TABLE 3.—*Average length in inches of redtop and Kentucky bluegrass leaves on various dates in 1914 and 1915, when grown alone and in mixture with white clover.*

Date.	Redtop.				Kentucky bluegrass.			
	Grass alone.		With white clover.		Grass alone.		With white clover.	
	Number.	Average length.	Number.	Average length.	Number.	Average length.	Number.	Average length.
1914.								
Nov. 23	88	0.76	98	0.79	137	0.64	126	0.86
1915.								
Aug. 21	36	.90	49	1.18	49	.85	55	1.23
Sept. 28	48	.97	69	1.03	61	.80	52	.95
Nov. 18	60	.71	58	.76	52	.64	46	.77
Average length	...	0.83	...	0.94	...	0.73	...	0.95

PERCENTAGE OF INCREASE IN THE PROTEIN CONTENT AND IN THE GROWTH OF GRASS LEAVES DUE TO THE EFFECT OF CLOVER.

The results which are presented in Tables 1 to 3 have been summarized in Table 4. In this table is presented the percentage of increase in the protein content and also the percentage of increase in length of leaf growth, in the timothy, redtop, and Kentucky bluegrass grown in mixture with clover over that in grass not grown in mixture with clover. This table shows that, in each of the four sets of plots, the clover had a somewhat greater effect on the growth in length of the leaves than on the percentage of protein. The average increase in protein content in all plots in grass grown with clover over that where the grass was grown alone is 13.02 percent; the average increase in length of leaf growth in the grass grown in mixture with clover is 21.01 percent.

TABLE 4.—*Percentage of increase in the protein content and in the length of leaf growth in grass grown in mixture with clover over that where the grass was grown alone.*

Grass.	Protein.	Length of leaf.
	Percent.	*Percent.*
Timothy grown in lawn plot	18.89	21.27
Timothy grown in field	7.68	19.41
Redtop	9.48	13.25
Kentucky bluegrass	16.03	30.13
Average	13.02	21.01

Effect of Clover on the Proportion of Green Leaves.

It has been observed, on plots of grass kept closely clipped with a lawn mower, that where clover is growing in mixture with grass the plot usually appears greener than adjacent plots where the same grass is growing alone. There are evidently two chief causes for this difference in color. The first one is the presence of the clover leaves, which are usually a comparatively deep shade of green and which grow in such a way that much of the underlying dry and brown parts of grass or other plants growing in the plot are hidden by them. The second cause for the greener color of the plots where clover is growing is the relatively larger number of green leaves on grass growing in mixture with clover than on grass growing alone. This fact is apparent in Table 5, which shows the percentages of green, partially green, and of dry brown grass leaves contained in samples of lawn clippings from plots of grass growing alone and in mixture with white clover. These samples were collected at New London, Ohio, on December 3, 1912.

Table 5.—*Proportion of green, partially green, and brown leaves on grass growing alone and in mixture with clover.*

Grass.	Green.	Partially green.	Brown.
	Percent.	*Percent.*	*Percent.*
Kentucky bluegrass:			
Alone	52.3	10.1	37.5
With clover	70.9	14.5	14.5
Creeping bent grass:			
Alone	28.5	27.8	43.6
With clover	42.2	25.2	32.5
Rhode Island bent grass:			
Alone	30.6	29.8	39.5
With clover	46.8	24.1	29.0

Table 5 shows that in each of the three instances given, the percentage of green grass blades is about 50 percent greater and the percentage of dry brown grass blades is smaller in each plot where the grass was grown in mixture with clover than in the corresponding plot where the grass was grown alone.

Effect of Clover on the Color of Grass Growing with It.

The tones of color of the green blades of grass in lawn clippings from plots where the grass was growing alone and from plots where it was growing in mixture with clover, have been compared at various times. When these comparisons were made, the green blades of grass were separated from the other components of the lawn clippings from each plot and placed on sheets of white paper. Usually little or no difference has been observed in the tone of color of the green leaves from the grass grown alone and from the grass grown with clover. At other times, especially in the samples of Kentucky bluegrass, the leaf blades from the plots of grass grown in mixture with clover have appeared somewhat darker green than the leaf blades from the corresponding plots where no clover was grown.

SUMMARY.

In 30 of the 31 comparisons which were made, the percentage of protein contained in the green leaves of timothy, redtop, and Kentucky bluegrass grown in mixture with clover was found to be greater than in the green leaves of the same grasses grown alone. It was also found that an application of ammonium nitrate caused an increased protein content in the leaves of timothy grown in plots where the fertilizer was applied. In the experiments reported here, the average increase in percentage of protein in the grass was somewhat greater where ammonium nitrate was applied than where the grass was grown in mixture with clover.

In each of 21 comparisons which were made, the growth in length of timothy, redtop, and Kentucky bluegrass leaves was found to be greater in plots where these grasses were growing in mixture with clover than where the same grasses were growing alone.

Lawn grass clippings from plots where the grass was growing in mixture with clover were found to be composed of a larger proportion of green leaves and a correspondingly smaller proportion of dry, brown leaves than lawn grass clippings from plots where no clover had been grown in mixture with the grass.

THE DRY-MATTER CONTENT OF FIELD-CURED AND GREEN FORAGE[1]

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INTRODUCTION.

Articles by Farrell[2] and McKee[3] on the basing of forage-crop yields on green weights suggest the presentation of data which permit a comparison to be made of the two methods of determining the yields of alfalfa and other forage crops, weighing the field-cured hay and weighing the crop green. These data were obtained under field conditions from a large number of plots.[4]

In the farm-crops work at University Farm during the year 1914 and for several years previously samples for dry-matter determination have been taken at the time the field-cured hay has been weighed. The yields on the different plots have been calculated in pounds of dry matter per acre based on these weights reduced to a uniform moisture content. There are two objections to this method of weighing and sampling: (1) All of the hay on any plot, although sufficiently field cured under canvas cock covers, is not always of uniform dryness throughout. Hence, there is considerable difficulty in securing a representative sample for dry-matter determination. (2) Under ordinary conditions where a considerable number of plots of alfalfa or mixed hay are to be cared for, rains interrupt the work at times and all or a portion of the hay is wet when partially cured. As a result more or less bleaching of the hay occurs and loss of leaves takes place, due to the additional handling necessary in drying. In many in-

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[1] Contribution from the Farm-Crops Section, Department of Agronomy and Farm Management, Minnesota College of Agriculture. Received for publication May 31, 1916.

[2] Farrell, F. D. Basing Alfalfa Yields on Green Weights. JOUR. AMER. SOC. AGRON., v. 6, no. 1, pp. 42–45. 1914.

[3] McKee, Roland. Moisture as a Factor of Error in Determining Forage Yields. (Introduction by C. V. Piper.) JOUR. AMER. SOC. AGRON., v. 6, no. 3, pp. 113–117.

[4] Since this article was prepared for publication, a bulletin (U. S. Dept. Agr. Bul. No. 353. 1916) entitled "Moisture Content and Shrinkage of Forage," by H. N. Vinall and Roland McKee, has also been published.

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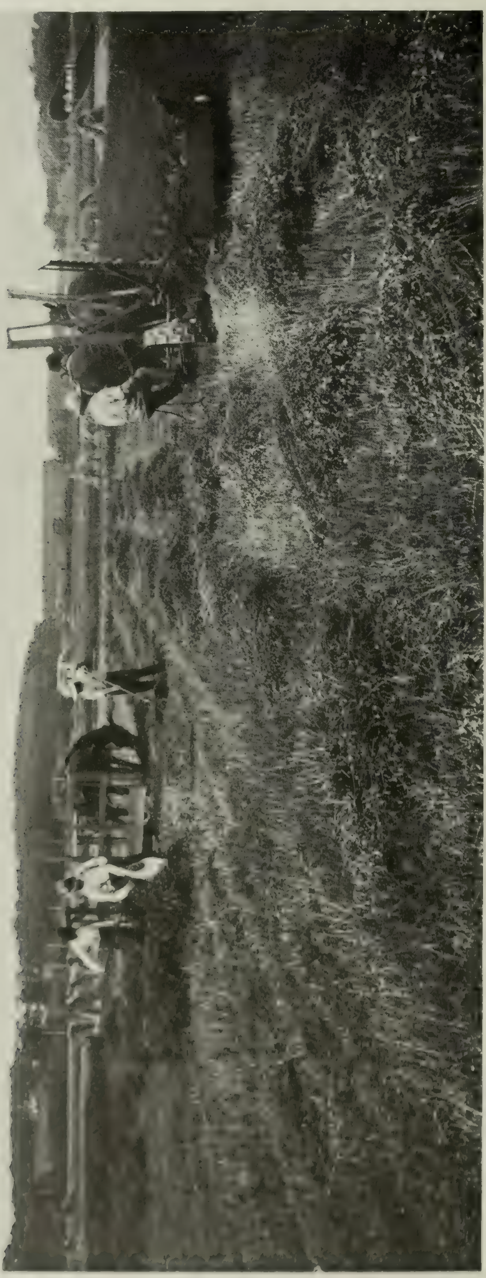

Cutting, weighing, and sampling alfalfa on the experimental plots of the Minnesota station.

stances this makes it very difficult if not impossible to obtain a representative sample for analysis.

In order to avoid these difficulties in some measure, plans were made early in the autumn of 1914 to weigh and sample all hay and other forage crops as soon as cut during the summer of 1915.

METHOD AND STAGE OF MATURITY OF CUTTING THE CROPS.

In 1914 and in previous years when the hay was field cured before weighing, the cutting was done with the mower and the hay was raked and cocked before it had become dry enough to lose any of the leaves. Canvas cock covers were used in order to secure the hay in the best condition. In 1915, when the alfalfa and other hay crops were weighed green, the cutting was done with a self-rake reaper. This machine leaves the material in a very convenient form for conveying it to the scales for weighing. As soon as the crop on one plot was cut it was weighed and a representative sample taken. Both years the alfalfa was cut when the new shoots at the crown were approximately 2 inches high. The timothy and clover crops were cut when the clover heads were beginning to turn brown. The sweet clover was cut when the buds were beginning to form.

METHOD OF WEIGHING AND SAMPLING.

The same method of weighing and sampling was used for the field-cured hay and for the crop weighed green. The weighing was done on a platform scale mounted on a sled made the width of the scale and 5½ feet long. The scale used has a double beam which simplifies the weighing. A rack which is so constructed as to permit folding when not in use held the material while it was being weighed. After the weight is taken, two men unload by tilting the rack backward. The horse then draws the scale forward as desired by the pitchers until sufficient material is secured for another weighing. One man does the weighing and secures the samples. The samples ranged from 1,000 to 1,500 grams in weight. The apparatus used in harvesting and weighing is shown in Plate XVIII.

The samples for dry-matter determination were put in cloth bags which had been previously weighed with the tag attached. The bag and its contents were weighed and the weight entered on the tag, on which the weight of the bag had been previously recorded. These data gave the net weight of each field sample. Each evening the samples were taken to the laboratory of the Division of Agricultural Chemistry and placed in a steam-heated oven. The samples from the third cutting of alfalfa in 1915 were hung until partially dry under the wide cornice of a low building where there was free circulation of air. They were then taken to the steam oven for completion of the drying process. After four to six days in the steam drying oven, when the material had ceased to lose weight, each bag and contents was weighed and from the completed data the percentage of dry matter was calculated.[5]

Basis of Comparison of the Two Methods.

The percentage of dry matter in field-cured forage is approximately from two to three times as great as in the same forage when green. Therefore, the mean of the dry-matter percentages for field-cured forage does not appear to be the proper basis for comparison with the mean of the dry-matter determinations of forage weighed green. The standard deviations in percentage of dry matter do not offer a good basis for comparison, since the weight of the total field-cured hay is so much less than the weight of the green material. A deviation of 1 percent in the dry-matter content of field-cured hay would be less serious than a deviation of 1 percent in dry-matter content of the same forage weighed green. The coefficient of variation appears to be the best common denominator. Therefore, the coefficient of variation is given in addition to the mean and the standard deviation.

The same plots were sampled in 1915 as in 1914. Eight different varieties and strains of alfalfa are included in the trial. The large majority of the plots are sown to the Grimm alfalfa and represent trials of different rates, methods, and dates of seeding and experiments with inoculation and liming. With the green material from so large a number of plots to handle, it was found to be impracticable to wait until all the dew was dried off each morning. The average yield per acre of field-cured alfalfa hay secured from these plots was 7,500 pounds. The average yield per acre of green alfalfa was 30,000 pounds. The data obtained on the percentage of dry matter in the field-cured alfalfa in 1914 and in the green alfalfa in 1915 are given in Table 1.

The following points are brought out in Table 1:

1. The range in the percentages of dry matter in the field-cured alfalfa hay is wide as compared with the range in those of the alfalfa weighed green. In both cases the range in percentage of dry matter

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[5] The thanks of the author are due and are hereby expressed to Prof. R. W. Thatcher, chief of the Division of Agricultural Chemistry of this Station, for making the weighings of the dried samples and the computations of percentages of dry matter in them.

TABLE 1.—*Range of dry-matter content in field-cured (1914) and green (1915) alfalfa in three cuttings from a large number of plots, with the standard deviations and coefficients of variation.*

CROP OF 1914 WEIGHED AND SAMPLED WHEN FIELD CURED.

Cutting.	Number of plots sampled.	Percentage of dry matter.					
		Highest.	Lowest.	Range.	Mean.	Standard Deviation.	Coefficient of variation.
First...	102	95.0	60.5	34.5	77.37 ± 0.44	6.56 ± 0.31	8.47 ± 0.40
Second.	102	96.0	66.0	30.0	86.02 ± 0.41	6.19 ± 0.29	7.19 ± 0.33
Third..	102	85.5	55.0	30.5	78.33 ± 0.31	4.64 ± 0.21	5.92 ± 0.27
Total..	306	96.0	55.0	41.0	80.39 ± 0.27	7.06 ± 0.19	8.76 ± 0.23

CROP OF 1915 WEIGHED AND SAMPLED AS SOON AS CUT.

First...	100	28.5	16.0	12.5	22.23 ± 0.16	2.45 ± 0.11	11.02 ± 0.52
Second.	102	27.0	16.0	11.0	20.67 ± 0.13	2.04 ± 0.09	9.86 ± 0.46
Third..	98	30.5	22.5	8.0	26.16 ± 0.17	1.87 ± 0.12	7.14 ± 0.46
Total..	300	31.5	16.0	15.5	23.01 ± 0.12	3.15 ± 0.07	13.69 ± 0.33

is probably somewhat larger than would result if the plots were all sown to one variety of alfalfa and other conditions were equal.

2. The mean percentage of dry matter in the field-cured alfalfa hay is 80.39 percent. The mean percentage of dry matter in the green alfalfa is 23.01 percent. These percentages are average for field-cured alfalfa hay and for alfalfa weighed green in the humid regions.

3. The coefficient of variation for the three cuttings of field-cured hay is 8.76 percent, with a probable error of 0.23 percent. For the three cuttings of alfalfa weighed green the coefficient of variation is 13.69 percent, with a probable error of 0.33 percent.

4. The coefficient of variation and the probable error are nearly twice as great for the alfalfa weighed green as for the field-cured alfalfa hay.

Timothy and clover crops in the same rotations were weighed and sampled in 1915 as in 1914. The white sweet clover weighed and sampled green was on different plots in 1915 than in 1914, but on the same field. The average yield of the two cuttings of field-cured timothy and clover hay per acre in 1914 was 8,061 pounds, and of the white sweet clover, 2,536 pounds. The sweet clover on half the plots in 1914 was not inoculated. This accounts for the very low average yield per acre. In 1915 the average yield per acre of timothy and clover weighed green was 15,636 pounds and of the white sweet clover weighed green, 19,330 pounds. The sweet clover on all of the plots in 1915 was inoculated. Data on the dry-matter content of these crops are given in Table 2.

TABLE 2.—*Range of dry-matter content in field-cured (1914) and green (1915) timothy and clover mixed and white sweet clover from a number of plots, with the standard deviations and the coefficients of variation.*

CROP OF 1914 WEIGHED AND SAMPLED WHEN FIELD CURED.

Cutting.	Crop.	Number of plots sampled.	Percentage of dry matter.					
			Highest.	Lowest.	Range.	Mean.	Standard deviation.	Coefficient of variation.
First...	Timothy and clover	18	87.0	60.7	26.3	83.55 ± 0.90	5.73 ± 0.64	6.84 ± 0.76
Second.	Do.	18	84.5	76.2	8.3	80.13 ± 0.32	2.04 ± 0.22	2.54 ± 0.28
Total..	Do.	36	87.0	60.7	26.3	81.84 ± 0.52	4.63 ± 0.36	5.65 ± 0.44
First...	Sweet clover	23	83.6	48.3	35.3	64.10 ± 1.59	11.34 ± 1.13	17.69 ± 1.75
CROP OF 1915 WEIGHED AND SAMPLED GREEN.								
First...	Timothy and clover	18	33.5	22.1	11.4	28.94 ± 0.46	2.94 ± 0.33	10.15 ± 1.14
Second.	Do.	18	49.8	26.1	23.7	37.63 ± 0.84	5.32 ± 0.59	14.10 ± 1.58
Total..	Do.	36	49.8	22.1	27.7	33.29 ± 0.71	6.32 ± 0.50	18.98 ± 1.50
First...	Sweet clover	31	19.5	12.8	6.7	16.19 ± 0.18	1.53 ± 0.13	9.45 ± 0.80

The following points are brought out in Table 2:

1. The range in percentage of dry matter is slightly lower for the field-cured timothy and clover than for this crop weighed and sampled green. In the alfalfa the range in the percentage of dry matter was greatest in the field-cured hay. For the white sweet clover the range in percentage of dry matter is nearly four times as great in the field-cured hay as in the sweet clover weighed green.

2. The coefficient of variation for the two cuttings of clover and timothy field cured is 5.65 percent, with a probable error of 0.44 percent. For the two cuttings weighed green it is 18.98 percent, with a probable error of 1.50 percent.

3. The coefficient of variation and the probable error are approximately three times as great for the timothy and clover weighed and sampled green as for that weighed and sampled when field cured.

4. The coefficient of variation for the field-cured white sweet clover is 17.69 percent, with a probable error of 1.75 percent. For that weighed green it is 9.45 percent, with a probable error of 0.80 percent.

5. The coefficient of variation and the probable error in the field-cured white sweet clover are approximately twice as great as those in the white sweet clover weighed green.

SUMMARY AND CONCLUSIONS.

1. The alfalfa and the timothy and clover mixed from a large number of plots, when field cured under canvas cock covers, in 1914, were less variable in dry-matter content than the product of the same number of plots weighed as soon as cut in 1915.

2. The white sweet clover was more variable in dry-matter content when weighed and sampled in the field-cured condition than when weighed and sampled as soon as cut.

3. Basing the weights of the product of the different plots on the field-cured hay gave a closer approximation of the correct weights of alfalfa and of timothy and clover mixed than weighing these crops as soon as cut.

4. The green weights of the white sweet clover gave a closer approximation of the correct weights of the product of the different plots than the field-cured weights.

5. When cut at the stages of maturity mentioned previously in this article, white sweet clover has a higher moisture content than alfalfa or timothy and clover mixed.[6] Therefore, sweet clover is not as easily field cured properly as alfalfa or timothy and clover mixed and securing a representative sample from it in this condition for dry-matter determination is a more difficult task.

6. A variation of 5 percent or more in the moisture content of the product from experimental plots is too great for reasonably accurate work. Therefore, it is not good practice to base weights of forage crops upon experimental plots on field cured weights or green weights. Samples for making corrections of yields on the air-dry or on the water-free basis are necessary for accurate work.

7. Where samples of the product of different plots are taken for making corrections of yields on the air-dry or moisture-free basis, weighing the product of each plot as soon as cut has proved to be the more desirable method of the two. This method is especially desirable where nitrogen determination or complete analysis is to follow the determination of dry-matter content.

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[6] Arny, A. C., and Thatcher, R. W. The Effect of Different Methods of Inoculation on the Yield and Protein Content of Alfalfa and Sweet Clover. JOUR. AMER. SOC. AGRON., v. 7, no. 4, pp. 172–185. 1915.

AGRONOMIC AFFAIRS.

NOTES AND NEWS.

Elmer D. Ball, entomologist and former director of the Utah station, has been elected state entomologist in Wisconsin and has begun his work there.

Robert K. Bonnett, formerly superintendent of the agronomy farm at the Kansas station, is professor of farm crops at the University of Idaho.

I. N. Chapman is county agent of Leavenworth County, Kans., with headquarters at Leavenworth.

Henry Cohn has succeeded C. E. Deardorff as assistant in soil survey at the Missouri station.

I. S. Cook, jr., agronomist of the West Virginia college and station, is now county agent of Ohio County, W. Va., with headquarters at Wheeling.

O. E. Harrington, formerly of the Michigan college, is teaching agriculture in the Western Normal College at Shenandoah, Iowa.

Sydney B. Haskell, formerly assistant agronomist of the Massachusetts college, is now in charge of the eastern office of the Soil Improvement Committee of the National Fertilizer Association, with headquarters at Baltimore, Md.

A. F. Head, of Ohio State University, is now an instructor in the department of soils in the Michigan college.

C. A. Helm, instructor in experimental agronomy at the Nebraska college, has been assistant professor of farm crops in the University of Missouri since the beginning of the college year.

Joseph H. Kastle, director of the Kentucky station, died at Lexington, Ky., on September 23, at the age of 53 years. Dr. Kastle was a graduate of Kentucky State University, with a doctorate degree from Johns Hopkins University. For several years he was professor of chemistry at the University of Virginia. In 1911 he took charge of chemical research at the Kentucky station, and the following year, on the death of Dean Scovell, was elected dean of the college of agriculture and director of the station.

M. A. Klein, formerly assistant in soils at the California station, is in charge of soil investigations with sugar beets at the Spreckels Sugar Co. experiment station at Spreckels, Cal.

REPORT OF THE SECRETARY FOR 1916.

The year's work has been marked principally by the general expansion of the Society. There has been a further and very marked increase in membership and, as will be noted more in detail elsewhere, an enlarged interest in the Journal. The more abundant funds and the larger number of papers sub- to Miss Jane B. Taylor and Miss Elizabeth C. Lambert, who have given valu- at the same time its high standard has been maintained. The increase in membership and in the number of papers printed has resulted in a material expansion of the work of the Secretary and Editor. That dual official urges a separation of the two offices, in order to afford at least a partial relief from present conditions.

The Secretary wishes to acknowledge the hearty cooperation of the Executive Committee and particularly of the efficient treasurer of the Society for the past several years, Professor George Roberts. Acknowledgment is also made mitted have made possible a further increase in the size of that publication, while able help during the year.

I. FUNDS COLLECTED BY THE SECRETARY.

The following is a classified list of the funds which have been received by the Secretary, chiefly from dues of new members and the sale of *Proceedings* and Journal. All these have been transmitted to the Treasurer and are included in his annual report.

Classified Receipts and Disbursements, July 22, 1915–October 27, 1916.

Receipts.

To dues collected (itemized list appended):

25 new members for 1915	at $2.00	$ 50.00	
1 new member for 1915	at 1.50[a]	1.50	
130 new members for 1916	at 2.00	260.00	
4 new members for 1916	at 1.50[a]	6.00	
30 local members for 1916	at .50	15.00	
2 new members for 1917	at 2.00	4.00	$336.50

To *Proceedings* and Journal sold:

10 copies of Volume 1	at $1.00	$10.00
1 copy of Volume 1	at 1.80[b]	1.80
4 copies of Volume 1	at 2.00	8.00
10 copies of Volume 2	at 1.00	10.00
1 copy of Volume 2	at 1.80[b]	1.80
5 copies of Volume 2	at 2.00	10.00
10 copies of Volume 3	at 1.00	10.00
1 copy of Volume 3	at 1.80[b]	1.80
5 copies of Volume 3	at 2.00	10.00

9 copies of Volume 4	at	1.00	9.00	
1 copy of Volume 4	at	1.80[b]	1.80	
5 copies of Volume 4	at	2.00	10.00	
12 copies of Volume 5	at	1.00	12.00	
1 copy of Volume 5	at	1.80[b]	1.80	
5 copies of Volume 5	at	2.00	10.00	
12 copies of Volume 6	at	1.00	12.00	
1 copy of Volume 6	at	1.80[b]	1.80	
6 copies of Volume 6	at	2.00	12.00	
7 copies of Volume 7	at	1.00	7.00	
1 copy of Volume 7	at	1.70[c]	1.70	
2 copies of Volume 7	at	1.80[b]	3.60	
8 copies of Volume 7	at	2.00	16.00	
10 copies of Volume 8	at	1.70[c]	17.00	
5 copies of Volume 8	at	1.80[b]	9.00	
17 copies of Volume 8	at	2.00	34.00	
1 copy of Volume 9	at	1.70[c]	1.70	
20 single numbers of Volume 5 to 8			5.41	$229.21
To extra reprints sold:				
From March–April number			$2.03	
				$ 2.03
				$567.74

Disbursements.

Nov. 1, 1915, by check to Treasurer Roberts	$ 88.50	
Jan. 3, 1916, by check to Treasurer Roberts	125.10	
March 1, 1916, by check to Treasurer Roberts	135.41	
June 1, 1916, by check to Treasurer Roberts	81.70	
Oct. 27, 1916, by check to Treasurer Roberts	137.03	$567.74
Balance on hand Oct. 27, 1916		$000.00

[a] Members of local sections who had previously paid dues of 50 cents each as local members.

[b] Sold through agents at 10 percent discount.

[c] Sold through foreign agent at 15 percent discount.

2. MEETINGS.

Only one meeting of the Society has been held this year, the present annual meeting. The joint meeting with the Great Plains Cooperative Association which was announced for August 22–24 at Amarillo, Tex., was abandoned because for several reasons it seemed best not to hold a meeting at that time.

The present assembly is the ninth annual meeting of the American Society of Agronomy. There have been 14 papers presented in our separate sessions and 2 in a joint session with the Society for the Promotion of Agricultural Science and the American Farm-Management Association. Of the latter, two were by members of this Society, these being the Presidential addresses of the Society for the Promotion of Agricultural Science and the American Society of Agronomy. The average attendance at the sessions of this Society has been about 90, while the attendance at the joint session was about 200.

3. LOCAL SECTIONS.

The Society now has nine local sections, located at Cornell University, Georgia State College, Iowa State College, Kansas State Agricultural College, Minnesota College of Agriculture, Ohio State University, South Dakota State College, in New England, and in Washington, D. C. The Georgia, Minnesota, Ohio, South Dakota, and New England sections were organized during the year. These nine local sections report memberships ranging from 10 to about 70. Most of them hold several meetings during the year, at which local agronomic problems are discussed. They have been productive of much good not only locally but to the Society. The membership at several other institutions is sufficient for the formation of local sections, and it is hoped that some of these will be organized in the next few months.

4. MEMBERSHIP.

The increase in membership of the Society in 1916 was greater than in any previous year. The American Society of Agronomy was organized on December 31, 1907. The membership reported in 1908 was 121. New members have been added since that time as follows: 1909, 26; 1910, 46; 1911, 71; 1912, 62; 1913, 64; 1914, 66; 1915, 107; and 1916, 147. The total number of members added since 1908 is 589, making the gross membership 710. In the eight years, 3 members have died, 25 have resigned, and 96 have allowed their membership to lapse, a total loss of 124. This is less than 20 percent of the gross membership, a remarkably low figure. The net membership at this time, therefore, is 586.

No special campaign for membership has been made, though sample copies of the Journal and circular letters were sent to about 300 agronomic workers in December, 1915. The increase has been due for the most part to individual effort on the part of the members and to the formation of local sections. While the growth of the Society is flattering, many agronomic workers still are not associated with us. It should be easily possible to add 200 members in 1917, and that number is needed if the plans of the Society are to be carried out.

Changed Addresses.

Of the 79 changes of address recorded in the Journal during 1916, 67 were due to changes of position. This number is 11 percent of the total membership, the same percentage of similar changes as was recorded in 1915.

The following is a complete list of those whose addresses are changed in the present issue:

Albrecht, Wm. A.
Ball, Elmer D.
Bonnett, Robt. K.
Chapman, I. N.
Cole, John S.
Crosby, M. A.
Gilbert, A. W.
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Graves, Geo. W.
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Haskell, S. B.
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Head, A. F.
Helm, C. A.
Hill, W. H.
Hitchcock, E. B.
Hutchison, C. B.
Klein, M. A.
Le Clair, C. A.
Lintner, W. A.
Milner, F. W.
Nash, C. W.
Olson, M. E.
Pope, M. N.
Richards, Phil E.
Schuster, G. L.
Seamans, A. E.
Stemple, F. W.
Stewart, Geo.
Turlington, J. E.
Wiggans, R. G.
Willey, L. D.
Wright, A. H.

NEW MEMBERS.

The total membership at the end of 1915 was 471. During 1916, 147 new members have joined the Society. During the same period 6 have resigned and 26 have allowed their memberships to lapse through nonpayment of dues. The total loss during the year is 32, leaving a net gain of 115 and a total membership of 586. A list of new members for 1916 follows. Those marked with the asterisk have joined since the previous issue of the JOURNAL. The addresses of all new members will be found in the address list of members.

New Members for 1916.

Abell, M. F.
Albrecht, Wm. A.
Alvord, Emory D.
Bachtell, M. A.
Bauer, F. C.
Beeson, M. A.
Bennett, Chas. D.
Biggar, H. H.
Blair, R. E.
Bliss, S. W.
Boardman, W. C.
Boyack, Breeze
Breithaupt, L. R.
Bruce, O. C.
Burlison, W. L.
Burnett, Grover
Bushey, A. L.
Cates, Henry R.
Chapman, I. N.
Collins, M. W. H.*
Cooper, H. P.*
Corson, George F.
Cowgill, H. B.
Curtis, Ernest W.
Davidson, Jehiel
Doryland, C. J. T.
du Buisson, J. P.
Duley, F. L.
Dunnewald, T. J.
Dustman, Robert B.
Edwards, R. W.
Ellis, Orland I.
Emerson, Paul
Ewan, A. E.
Fisher, Forest A.
Florell, Victor H.
Freeman, Geo. F.
[illegible], Raymond C.
Gilkerson, H. C.
Gish, N. A.
Goodall, S. E.
Graber, L. F.*
Graves, Geo. W.
Hall, E. W.
Harrison, T. J.
Headley, F. B.
Hearn, W. E.
Helm, C. A.
Hill, W. H.
Hitchcock, E. B.
Holbert, J. R.
Horton, Horace E.
Hutcheson, T. B.
Jennings, D. S.
Jensen, Chas. A.
Jensen, O. F.
Justin, M. M.
Karlstad, C. H.
Karper, R. E.
Kephart, L. W.
Kyle, C. H.
Laidlaw, C. M.
Lapham, Macy H.
Ledyard, E. M.
Leith, B. D.
Leonard, Lewis T.
Lintner, W. A.
Lofinck, R. E.
Lyness, W. E.
McAdams, James
McClymonds, A. E.
McLane, J. W.
McMillan, S. A.*
McMiller, P. R.
McQuarrie, C. K.
Mally, F. W.
Maris, Edwin I.
Martin, Thomas L.
Miles, F. C.
Milner, F. W.
Moore, Harvey L.
Morgan, O. S.
Nuckols, Sam'l B.
Ogaard, A. J.
Osborn, W. M.
Osler, H. S.
Palm, A. W.*
Palmer, H. Wayne
Parker, J. H.
Paxman, J. W.
Pendleton, R. L.
Petry, Edward J.
Phillips, Thos. G.
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Quigley, J. V.
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Richards, Phil E.
Rose, C. M.
Rost, C. O.
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Salter, Robt. M.
Sarvis, J. T.
Schaub, I. O.*
Schick, G. M.
Schneiderhan, F. J.
Schulz, Arthur W.
Schuster, G. L.
Scott, Herschel
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Severance, George
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Stanley, Clarence W.
Stephens, David E.
Stewart, H. W.
Stewart, Rupert L.
Stokes, W. E.
Stookey, E. B.
Tabor, Paul
Thatcher, L. E.
Towle, R. S.
Townsend, C. O.
Truog, Emil
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Vivian, Alfred
Waller, Adolph E.
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Westley, Roy
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Wimer, David C.
Winwright, George
Withycombe, Robt.
Wolfe, T. K.
Wright, A. H.
Young, Harry P.
Young, Horace J.
Zahnley, J. W.

Distribution of Membership.

Of the 586 members of the Society, 548 reside in the continental United States and seven in our island dependencies. Of these seven, four are in Hawaii, two in Porto Rico, and one in the Philippines. Every State has at least one member, and all save four have three or more members. The largest membership, 71, is in the District of Columbia. The States where the Society has 10 or more members, with the number in each, are as follows: Kansas, 34; Illinois, 31; Ohio, 25; New York, 24; California, 23; Texas, 22; North Dakota and Iowa, 20 each; Indiana, 19; Minnesota, 18; Wisconsin, 16; Georgia, Oregon, and South Dakota, 15 each; and Maryland, Massachusetts, and Washington, 10 each. We have 20 members in Canada, representing eight Provinces, and 1 in Costa Rica, 2 in Cuba, and 2 in Brazil. Our membership outside the Americas numbers 6, 2 each in China, India, and South Africa.

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5. JOURNAL AND PROCEEDINGS.

The bimonthly issuance of the JOURNAL has been continued during 1916, but with a material increase in the size of the numbers. Four 64-page and one 80-page number have been printed, while the remaining number will consist of 64 pages, making a total of 400 for the volume. Compared with previous volumes, this is an increase of 25 percent over Volume 7 (1915), of 36 percent over Volume 6 (1914), and of 56 percent over Volume 5 (1913). Including those in the November–December number, 44 papers have been printed. Eighteen plates and 10 text figures have been used in illustrating these papers. The 44 authors represent 15 States, the District of Columbia, and Porto Rico. All but one of the five numbers so far issued have appeared on time. There will necessarily be some delay in the issuance of the sixth number, in order to include a report of the annual meeting.

By decision of the Executive Committee, 50 free reprints are now supplied to the authors of each paper published in the JOURNAL. While this practice has resulted in a considerable increase in the cost of publication of our magazine, it is believed to be an expense which is fully justifiable. The free reprint privilege appears to be appreciated by our contributors.

The next step in advance should be toward monthly issuance. Our financial condition does not yet justify that step, but a partial advance can be made by issuing nine or ten 48-page numbers, these to appear monthly except in June, July, and August, or except in July and August, as the case may be. Whether or not this can be done will depend on the increase in membership in the next two months. Monthly issuance will make possible much more prompt publication of papers than at present, and in many other ways seems desirable. Every member can hasten its coming by bringing the Society to the attention of his friends.

DISPOSAL OF PUBLICATIONS.

In Table 1 will be found full data on the disposal of *Proceedings* and JOURNAL during the period from July 22, 1915, to October 27, 1916.

The sale of the publications of previous years has continued about as usual, the greater part of these volumes going to members who desired to complete their sets of *Proceedings* and JOURNAL. The number of copies of the current volume distributed to libraries shows a decided increase over last year, being

77 as compared with 56, an increase of 37½ percent. The total income from the sale of volumes other than the current one was $162.10, of which $133.10 was received in the 12-month period since November 1, 1915. Through an unfortunate error the edition of the current volume was not increased over that of previous years, so that the number remaining in stock is much smaller than was planned.

TABLE 1.—*Data showing the original edition of each volume of the Proceedings and Journal, the distribution made previous to and during 1916, and the number of copies remaining in stock.*

Edition printed, disposition of copies, and number remaining.	Volumes.							
	1	2	3	4	5	6	7	8
Edition printed	501	517	516	514	750	750	750	750
Previously accounted for	349	357	386	396	620	496	531	...
Distributed to members, 1916	...	...	...	...	...	...	26	586
Distributed to subscribers, 1916	...	...	...	...	...	...	...	42
Sample copies	...	...	...	...	...	...	...	9
Sold, 1916	15	16	16	15	18	19	18	31
Total copies distributed	364	373	402	411	638	515	575	668
Difference	137	144	114	103	112	235	175	82
Sold on credit orders	1	1	1	1	1	1	1	4
Copies in stock	136	143	113	102	111	234	174	78

6. MINUTES OF THE ANNUAL MEETING.

WASHINGTON, D. C., NOVEMBER 13–14, 1916.

First Session, Monday Afternoon, November 13.

The meeting was called to order in the New Ebbitt Hotel at 2 p.m. by President Ball and the presentation of papers on the regular program was taken up, as follows:

1. The Possible Rôle of the Active Organic Matter of the Soil, by Mr. C. J. T. Doryland (read by the Secretary in the absence of the author).

2. Field Crops and Bacterial Transformation of Soil Nitrogen (illustrated), by Dr. K. F. Kellerman and Mr. R. C. Wright (presented by Mr. Wright).

3. The Carbon Dioxid Content of a Planted and Unplanted Limed and Unlimed Soil, by Drs. T. L. Lyon and J. A. Bizzell (presented by Dr. Lyon).

4. A Method of Determining the Volume Weight of Soils in the Field, by Prof. C. F. Shaw.

5. Studies on the Relation of the Cob to Other Ear Characters in Corn (illustrated), by Prof. A. E. Grantham.

The reading of the papers being concluded, President Ball announced two special committees, as follows:

NOMINATING COMMITTEE.

C. A. Mooers, *chairman;* E. O. Fippin and J. W. Gilmore.

AUDITING COMMITTEE.

J. R. Fain, *chairman,* and H. N. Vinall.

After announcements by the Secretary regarding the agronomists' dinner, the joint evening session, the next day's sessions of the Society, the payment of dues, and applications for membership, the session adjourned.

At 6 o'clock an agronomists' dinner was served at the New Ebbitt Hotel, at which 45 members of the Society were in attendance.

Second Session, Monday Evening, November 13.

This session was held jointly with the Society for the Promotion of Agricultural Science and the American Farm-Management Association for the presentation of the presidential addresses of the three organizations. It was called to order by Dr. W. J. Beal, presiding, with about 200 persons present. The following papers were presented:

Our Place in the Sun, by Dr. C. E. Thorne, President of the Society for the Promotion of Agricultural Science.

Some Problems in Agronomy, by Mr. Carleton R. Ball, President of the American Society of Agronomy.

How the Investigator of Farm-Management Problems Can Help the Farmer, by Mr. H. W. Jeffers, Vice-President of the American Farm-Management Association.

After announcements regarding the next sessions of the various organizations, the joint session adjourned.

Third Session, Tuesday Morning, November 14.

The session was called to order by President Ball at 9 a.m. The reading of papers was resumed, as follows:

6. Composts as an Aid in Soil Building, by Dr. J. G. Lipman.

7. The Relation of Livestock to the Maintenance of Organic Matter in the Soil, by Prof. E. O. Fippin.

8. What is Agronomy? by Prof. A. N. Hume (read by the Secretary in the absence of the author).

The business session followed the reading of Professor Hume's paper.

(*Business Session.*)

On motion, the minutes of the last annual meeting as printed in the JOURNAL (7: 309–311) for November–December, 1915, were approved.

The report of the Secretary was read and, on motion, approved.

The report of the Treasurer was read and, on motion, approved.

The report of the Auditing Committee was read by the chairman, Prof. Fain, and was approved, on motion.

The report of the Executive Committee was read by the Secretary and, on motion, was approved.

The report of the Committee on Soil Classification and Mapping was read by the chairman, Dr. C. F. Marbut, and was approved, on motion.

The report of the Committee on Standardization of Field Experiments was presented by the chairman, Dr. T. L. Lyon, and, on motion, was approved.

The report of the Committee on Agronomic Terminology was read by the chairman, Prof. Charles V. Piper, and was approved, on motion.

The report of the Committee on Varietal Nomenclature was read by the chairman, Prof. E. G. Montgomery, and was recommitted, on motion, with instructions to the Committee to present the matter of official registration in greater detail at the next meeting of the Society and to the Secretary to provide ample time for discussion of the subject at that meeting. On motion, the chairman of the committee was given authority to present the matter of an official registration of crop varieties and crop names informally to the Secretary of Agriculture.

The Nominating Committee reported the following nominations for officers of the Society for the year 1917:

President, Director W. M. Jardine, Kansas Experiment Station.
First Vice-President, Dr. J. G. Lipman, New Jersey Expt. Station.
Second Vice-President, Prof. J. A. Foord, Massachusetts Agr. College.
Secretary, Mr. C. W. Warburton, U. S. Department of Agriculture.
Treasurer, Prof. George Roberts, Kentucky Expt. Station.

On motion, the chairman was instructed to cast the ballot of the Society for the nominees and, this being done, they were declared elected to the respective offices.

The following amendments to the by-laws were proposed and, after explanation by the Secretary, were adopted, on motion:

"Amend by-law 1 by substituting for the words 'which shall be paid on or before April 1,' the words 'which are due and payable on January 1,' the by-law then reading: 'The annual dues for each active and associate member shall be $2.00, and for each local member 50 cents, which shall be due and payable on January 1 of the year for which membership is held.'"

"Insert a new by-law as by-law 2, the present by-law 2 becoming by-law 3, and so on, the new by-law 2 to read: 'The JOURNAL of the American Society of Agronomy shall not be sent to any member whose dues are not paid by April 1 of the year for which membership is held.'"

On motion, the Society expressed its thanks to the management of the New Ebbitt Hotel for courtesies extended during its sessions.

The Society then adjourned to meet at 2 p.m.

Fourth Session, Tuesday Afternoon, November 14.

The session was called to order by President Ball at 2 p.m. The reading of papers was resumed, as follows:

9. The Sugar Beet as a Factor in National Preparedness (illustrated), by Dr. C. O. Townsend.

10. The Soil Mulch (illustrated), by Messrs. L. E. Call and M. C. Sewell (presented by Mr. Sewell).

11. A New Device for Harvesting Grass and Grain Plots, by Prof. A. G. McCall.

12. The Effect of Inoculation on Yield and Protein Content of Alfalfa and

Sweet Clover—2, by Mr. A. C. Arny and Dr. R. W. Thatcher (presented by Dr. Thatcher).

13. Heating Seed Rooms to Destroy Insects, by Prof. E. G. Montgomery.

14. The Effect of Sodium Nitrate Applied at Different Stages of Growth on the Yield, Composition, and Quality of Wheat, by Drs. J. Davidson and J. A. LeClerc (presented by Dr. Davidson).

The presentation of papers being completed, the Society adjourned, *sine die.*

REPORT OF THE TREASURER.

From July 31, 1915 to November 13, 1916.

Receipts.

Balance on hand, July 31, 1915		$ 518.74
From the Secretary, C. W. Warburton, per his statements Nos. 1–5		567.74
Membership fees received:		
For 1914	$ 2.00	
For 1915	168.00	
For 1916	652.00	
For 1917	10.00	
Local memberships	1.50	
Fees for collecting checks	.30	833.80
Receipts from libraries for Journal:		
For Volume 7	10.00	
For Volume 8	74.00	
Extra copies	7.10	91.10
Total receipts		$2,011.38

Disbursements.

			Voucher No.		
1915.					
Sept.	7.	W. T. Clark, clerical assistance, etc., at Berkeley meeting	77		$ 9.85
Sept.	7.	Lewis M. Thayer, printing	78	$ 9.50	
Oct.	11.	do.	80	11.00	
Dec.	10.	do.	84	14.00	
1916.					
March	10.	do.	92	8.75	
July	27.	do.	99	7.25	
Sept.	20.	do.	101	2.75	
Oct.	31.	do.	105	20.00	73.25
1915.					
Oct.	11.	Maurice Joyce Engraving Co., cuts	81	24.30	
Nov.	17.	do.	83	6.00	
1916.					
Jan.	28.	do.	87	11.98	
March	10.	do.	91	14.00	
May	6.	do.	95	11.00	
July	3.	do.	98	13.40	
Aug.	31.	do.	100	30.90	
Oct.	31.	do.	104	12.41	123.99

1915.				
Sept. 7.	New Era Ptg. Co., printing JOURNAL, 7^4...	79	115.34	
Dec. 16.	do. 7^5...	85	162.92	
1916.				
Feb. 15.	do. 7^6...	88	191.45	
June 19.	do. $8^{1,2}$...	97	352.55	
Sept. 30.	do. $8^{3,4}$...	102	362.51	
Oct. 30.	New Era Ptg. Co., printing reprints from JOURNAL, 8^4	103	20.26	1,205.03
1915.				
Nov. 27.	C. W. Warburton, Secretary's expenses ...	82	15.15	
1916.				
Jan. 15.	do. ...	86	18.75	
March 9.	do. ...	90	27.10	
June 5.	do. ...	96	19.80	
Oct. 31.	do. ...	106	40.03	120.83
March 1.	Lexington, Ky., postoffice, stamps	89		15.00
March 23.	Jessie Caswell, clerical help	93		2.00
April 17.	State University Press, bill heads and envelops	94		3.25
	Total disbursements			$1,553.20
	Balance November 13, 1916			458.18
				$2,011.38

GEORGE ROBERTS,
Treasurer.

AUDITING COMMITTEE'S STATEMENT.

The undersigned committee, appointed to examine the accounts of Mr. Geo. Roberts, Treasurer of the American Society of Agronomy, report that they have examined the books and statements of the Treasurer and find the condition of the Society's finances as set forth in Mr. Roberts' annual report correct.

JOHN R. FAIN,
H. N. VINALL,
Auditing Committee.

REPORTS OF COMMITTEES.

The reports of two special committees, those on audit of accounts and on nominations, are found elsewhere. The Auditing Committee's report immediately follows the report of the Treasurer, while that of the Committee on Nominations appears at the proper place in the minutes of the business session.

The reports of the four standing committees of the Society follow the report of the Executive Committee.

REPORT OF THE EXECUTIVE COMMITTEE.

There has been no meeting of the Executive Committee during the year, such matters as have required attention by the committee having been decided by mail vote.

In December, by a mail vote, it was ordered that 50 free reprints, without covers, be supplied to the authors of each paper published in the JOURNAL; that subscription agents be allowed a commission of 10 percent on subscriptions to the JOURNAL; that the Committee on Soil Classification and Mapping be reduced from 15 to 5 members; and that charters be granted to local sections at the Minnesota College of Agriculture and Ohio State University.

In May, by a mail vote, it was ordered that charters be granted to a local section of New England agronomists and to a local section at the Georgia College of Agriculture. It was also decided that the JOURNAL should not be offered in exchange for other publications.

REPORT OF THE COMMITTEE ON SOIL CLASSIFICATION.

When the Committee on Soil Classification and Mapping was reorganized early in 1916 the members thought that an examination of the criteria by which soil units are separated, identified, and described would be of more value at present than the discussion of the arrangement of soils in a scheme of classification. As soil differentiation has been carried out in more detail in this country than elsewhere it seemed desirable to determine whether the bases for this minute differentiation were justifiable both as to quality and quantity and to discuss the advisability of recommending additional bases.

With this object in view the Chairman requested each member to discuss, in the first meeting of the Committee, the extent to which some particular phase of the subject should enter into the definition of soil units. Dr. Briggs was asked to discuss the phase of physical examination of soils in the field and of samples in the laboratory; Dr. Alway, that of chemical examination of soils; Dr. Coffey, that of climatic variations; Prof. Fippin, that of geological origin and structure; and the Chairman, that of the physiography of the region of occurrence. The Committee had two meetings during the week from November 13 to November 18, and reached the following conclusions with more or less dissent. They are submitted to the members of the Society for their consideration and for discussion at some future meeting.

Chemical Examination. At the present time the results of chemical analyses or other studies are not made a basis for soil differentiation except in very general terms. In a number of States chemical studies of soil types are being made but the types are defined and differentiated without direct reference to their chemical composition so far as details are concerned.

In the U. S. Soil Survey the lime content is being made a basis of separation in a broad way. Soils that have a content of lime carbonate sufficiently high to cause effervescence in acid are differentiated from those that do not effervesce, even when all other characteristics are alike. Those effervescing in the surface soil are differentiated from those effervescing only in the lower part of the 3-foot soil section. No concerted attempt has yet been made to separate the great number of soils in which the lime carbonate content is too low to effervesce into groups on the basis of the lime content, though the readiness with which clover and alfalfa grow is receiving more and more attention in soil differentiation.

It was agreed, on the recommendation of Dr. Alway, that the adequacy of the lime content should be used as a basis for separating soils and defining soil units. The number of soil groups to be established on this basis of determination was not discussed, nor were methods of determination taken up. There was some expression of opinion that the total quantity of the lime present in the various soil horizons, as well as the form in which it occurs, should be determined also, and that for purposes of scientific rather than mere agricultural differentiation this would be more important than the adequacy.

The organic matter of the soil is and has long been used as a basis of soil differentiation but only through its effect on the color of the soil. The Committee was unanimous in its approval of the recommendation of Dr. Alway that differentiation be based on a more accurate determination of the organic matter. No agreement was reached as to the range in percentage to which each soil unit should be restricted nor the number of units between the lowest and highest percentage present in soils. Before plans are made for carrying this recommendation into force it should be determined whether the existing work, in which differentiation is based on soil color, is inaccurate.

It was further suggested by Dr. Alway that the total organic matter in the soil could be determined with sufficient accuracy by multiplying the total nitrogen by a factor, avoiding in this way the more tedious and difficult determination of the organic matter by more direct methods. No criticism of this suggestion was made by any member of the Committee.

Two other questions were raised by members of the Committee: (1) In sampling soil for chemical analysis, the results to be used as a basis of differentiation, should the sample be collected from a cultivated field or from an area of virgin soil? The majority of opinion was decidedly in favor of collecting samples from areas of virgin soil. (2) Should samples be collected uniformly by inches, collecting all surface soils to a uniform depth, regardless of the character of the soil, or should they be collected according to the horizons of which the soil profile is made up? The opinion of the Committee was not unanimous, though the majority inclined to the opinion that each horizon should be sampled, regardless of its thickness.

Dr. Alway recommended a separation of peat or muck soils on the basis of the adequacy of their lime content and also on the depth or thickness of the peaty or mucky layer.

It was further agreed that for purposes of classification complete chemical analyses by the fusion method should be made of all the main soil types.

Physical Examination. Dr. Briggs suggested the determination of the moisture equivalent of soils and the use of the results as a basis of separation and definition. In order to determine the relation of these results to those obtained by the ordinary mechanical analysis now in almost universal use, it was recommended and approved by the Committee that comparative studies be made of the same soils by the two methods. The determination of the moisture equivalent would be preferable to the ordinary mechanical analysis, in case their results have equal significance, because of the greater rate at which the former could be obtained in a properly equipped laboratory.

It was agreed also that the proper range to be permitted in each soil class should be determined by making a great number of determinations of soils of each class as now recognized in the field, adopting the extreme figures as the range limits of the given class. It was thought advisable also that an expression denoting the moisture equivalent should follow the name of a soil in the heading of chapters describing the soil in a survey report. The moisture equivalent should not take the place of mechanical analysis and the figures expressing it should not take the place of the ordinary soil class name, but both could and should be supplemented by them.

The study of the colloids in the soil has attracted a great deal of attention in recent years. In the ordinary mechanical analysis the percentage of material that, on the basis of the size of the individual particles without reference to their crystalline or amorphous condition, could be classed as colloidal is not determined, though it has long been thought by many investigators that in many soils it is of great importance.

The Committee was unanimous in its approval of Dr. Briggs's suggestion that the percentage of material in which the diameter of the particles is less than .0001 mm. should be determined and where considerable in amount it should be used as a basis of differentiation and definition of soil units. No attempt was made to define the minimum amount that should be so recognized.

Climate. When we pass to the consideration of the extent to which climate should enter into the definition of a soil unit we leave the consideration of soil characteristics as such and pass to that of forces which produce those characteristics. It brings up directly the question of the propriety of basing soil definition and identification on features of soil environment rather than of soils. To recognize such factors is equivalent to the recognition of the same factors in biology and other natural history sciences. There would seem to be no more reason for the definition of soils on the basis of their climatic environment than there is to define plants on the same basis. To be sure, plants differ in accordance with their climatic environment, but they are defined on the basis of effects produced by that difference rather than on that of the environment. In their systematic definition and description they are not described as arid or humid plants, though we discuss them in general terms as having been developed under the influences of various climatic environments.

It was unanimously agreed by the Committee, on Dr. Coffey's recommendation, that the systematic definition of soil units should not be based on their climatic environment but on the soil characteristics produced by that environment.

was made to define the minimum amount that should be so recognized.

a soil unit, discussed by Professor Fippin, involves essentially the same questions as those arising in the matter of climate. It has been demonstrated by studies in this country and Europe that after a soil has reached what might be called the mature stage of its life, its hereditary or rock-derived characteristics have either disappeared entirely or have become of minor importance. Characteristics of the parent rock from which a soil is derived are not permanent therefore and cannot be applied to soil universally. The Committee was unanimous in their agreement with Prof. Fippin that while a field soil man should be able to recognize geological features and changes of such in the field, yet the soils he identifies should be defined in terms of soil characteristics instead of those of the parent rock. The recognition of geological conditions and changes in the field will suggest to the soil student certain soil features to be looked for and which might not be noticed without such suggestions.

Physiography. On account of the lack of time there was not a full discussion of the use of physiographic features as bases for soil definition.

There was general agreement that physiography, defined as relief of the land, either regional or local, has no greater claim for recognition in the matter than has climate and geology. Where the physiography of two localities is sufficiently different to bring about a difference in soil development through variation in climatic factors the difference should be recognized, but this becomes a recognition of soil rather than of physiographic differences. The

Committee was unanimous in the opinion that an attempt to define soils on the basis of differences in climate and physiography was an attempt to confuse the description of objects with their geography and environment.

C. F. Marbut,
Chairman.

REPORT OF COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

Your committee as organized at present met for the first time just before this meeting of the Society. It was decided to compile a bibliography of the published articles dealing with methods of field experimentation, and to review the articles dealing with the following subjects:

1. Size of plots for field experiments with crops.
2. Size of plots for field experiments with soils.
3. The use of check plots.

T. L. Lyon,
W. M. Jardine,
A. T. Wiancko,
Committee.

REPORT OF COMMITTEE ON AGRONOMIC TERMINOLOGY.

Your Committee on Terminology presents the following report of its activities during the past year:

To bring about a more accurate use of agronomic terms, your committee has deemed it wise to prepare a glossary of agronomic terms, with the idea of having this issued when complete under the official indorsement of the Society. On account of the large amount of labor involved, it has seemed best to issue the parts as completed under the title "Contributions to Agronomic Terminology." The four parts already prepared have been printed in the Journal during the year. By this means we have succeeded in getting many helpful criticisms and suggestions from members of the Society. These are greatly appreciated and will help make the finished glossary more satisfactory.

Your committee has thus far published mainly on terms already well defined and has proposed but few new ones. The looseness of usage due to ill definition of many agronomic terms presents a difficulty which your committee hopes to surmount without proposing an undue number of new words. It is hoped that the entire glossary may be completed within a year from date.

Messrs. L. C. Corbett and O. F. Cook have kindly agreed to aid your committee as consulting members.

Respectfully submitted,

C. V. Piper,
C. R. Ball,
H. L. Shantz,
Committee.

REPORT OF THE COMMITTEE ON VARIETAL NOMENCLATURE.

The Committee on Varietal Nomenclature was first appointed at the annual meeting of the Society held in Columbus, Ohio, in November, 1911 (Proc. Amer. Soc. Agron., 3: 20. 1911). The present chairman at that time read a paper, in which he pointed out the prevailing confusion in regard to varietal names of crop plants. This statement was based on a study of some 500 samples of oats collected from experiment stations and seedsmen, which showed very clearly that the same name was often applied to several different varieties.

The committee, however, was not able to offer a practical plan or solution, although the situation was studied. A brief article was reported by the chairman at the meeting of 1914 (Jour. Amer. Soc. Agron., v. 7, no. 1, p. 29. 1915), with comments by the editor (p. 40). At this time the desirability of establishing some sort of official registry was suggested. Later an article by Dr. W. C. Etheridge (Jour. Amer. Soc. Agron., v. 7, no. 4, p. 186. 1915) was published, emphasizing the present confusion in regard to the nomenclature of oats, of which the following is an extract:

> "The material from which this description was drawn is included among about 700 so-called varieties and duplicates collected for classification from 40 experiment stations and 53 seedsmen. Among 36 lots bearing the name 'Swedish Select,' from 22 stations and 8 seedsmen, only 23 are alike; and these constitute the variety here described. Of the 22 stations 6 were growing varieties other than Swedish Select under that name. Of the 8 seedsmen 2 were selling other varieties under the name 'Swedish Select.' In a few cases several widely different forms had been grown as Swedish Select by the same station. Among 13 lots which did not conform to the type, the forms ranged from varieties closely resembling Swedish Select to side panicle oats and, in one case, to Red Rustproof.
>
> "On the other hand, the Swedish Select form occurred among the 700 lots under 93 different names and variations of names, while most of these names were in turn applied to other different forms. Frequently the misnomers were 'pedigreed' or 'selected' numbers of various experiment stations. In other cases, such popular names as National, Lincoln, Roosevelt, President, Banner, Twentieth Century, Golden Fleece, and Prosperity were applied to the Swedish Select and to other different forms as well."

Finally, at the Berkeley meeting in August, 1916, the committee made a rather full report, reviewing the very encouraging progress that had been made during the past three years on the classification of economic plants, and pointing out the need of devising some plan for making more practical use of these studies.

The principal value of the committee's efforts so far has been to call attention to the present condition, to stimulate interest, and to collect opinions as to some practical plan which might be adopted for improving the situation. After due consideration the committee wishes to offer the following report, together with certain resolutions, for the consideration of the Society.

Suggestions of the Committee.

1. *Registration of Varieties.*—Discussion in the past has led to the general conclusion that some plan of registration for all known varieties should be worked out, with provision for adding new introductions. The registry would be something on the plan of a herdbook, with a history and description of each variety.

2. *Classification Necessary.*—However, before registration can be undertaken, all varieties should first be classified into natural groups and types. This classification should include a complete description of each type or variety, with keys so that any new variety could be readily assigned to its proper type. The first step is to secure satisfactory classifications of cereals. As an example of this attention is called to "A Classification of Oats" by Dr. W. C. Etheridge (Memoir N. Y. Cornell Agr. Expt. Sta., in press). This and other similar classifications might well be adopted as a basis for registration.

3 *Type Names and Numbers.*—When the classification is complete, each distinct type should be designated by some appropriate name and number. All synonyms should be grouped under this type, and any new variety not distinguishable by fixed and visible characters should be grouped under its proper type. It would then only be necessary for students to learn the characteristics of each type.

4 *Variation within Types.*—There are, however, many invisible characters not subject to classification, such as yielding power. For example, there might be several varieties belonging to the Silvermine type not distinguishable by visible characters and yet differing in yielding power or in adaptation to different conditions. When such differences are known or determined, they should be recorded.

5. *Method of Registration.*—At first, known varieties should be properly registered. Then any new variety should first be examined and its proper place in the classification designated. Then a careful detailed description should be given, which should include its origin, history, and particular economic value or adaptations. A plan for advanced registration should also be made for those registered types which have proved their superior merit.

6 *Responsibility for the Registry.*—While the American Society of Agronomy should be officially responsible for the work, some plan must be adopted for carrying out the details.

(*a*) Certain qualified individuals might be chosen by the Society, each of whom would supervise the registration of some particular crop, as oats or barley.

(*b*) The United States Department of Agriculture might be asked to provide a specialist whose duty it would be to care for this work and promote the general adoption of the classification when once established.

PROPOSED MOTIONS.

In order to place before the American Society of Agronomy a plan of definite action for its consideration, the following motions are proposed.

1 *That the United States Department of Agriculture, Bureau of Plant Industry, be asked to provide a specialist who shall be in charge of a central office located in Washington. The duties of this specialist shall be to supervise the general registration of each crop and to promote the general adoption of the classification when once established. This specialist shall be known as the Registration Secretary. Two members of the American Society of Agronomy shall be appointed for each crop or group of crops, these members to act with the registration secretary as a registration committee for that crop or group of crops*

We further recommend that:

(*a*) *This crop committee shall have charge of the preparation of proper blanks which shall give accurate descriptions of each variety which is proposed for registration, giving the variety its correct name and number and proper place in the classification.*

(*b*) *An essential part of the registration shall consist of the preparation of a permanent mount of the variety under direction of the registration secretary and thus a complete file in the main office of all registered varieties.*

(*c*) *The registration secretary shall have charge of the preparation of printed descriptions and mounted specimens and seed stocks of all registered varieties which shall be sold at cost to members of the American Society of Agronomy, officials of the Department of Agriculture, and of the state experiment stations.*

If the above plan is not found practical, we then propose that:

2. *A committee of two prominent investigators for each important field crop be appointed by the American Society of Agronomy who, together with the Committee on Varietal Nomenclature, shall have charge of obtaining and adopting a system of classification for that particular crop. After adoption this classification shall be published in the* JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY. *Such classification shall be used until amended by action of the Society.*

So far as possible each committee shall carry out the recommendations in the first motion, namely:

(*a*) *This crop committee shall have charge of the production of proper blanks which shall give accurate descriptions of each variety which is proposed for registration, giving the variety its correct name and number and proper place in the classification.*

(*b*) *That an essential part of the registration shall consist of the preparation of a permanent mount of the variety under direction of the registration secretary and thus a complete file in the main office of all registered varieties.*

(*c*) *That the registration secretary shall have charge of the preparation of printed descriptions and mounted specimens, and seed stocks of all registered varieties which shall be sold at cost to members of the American Society of Agronomy, officials of the Department of Agriculture, and of the state experiment stations.*

PROPOSED FORMS.

The Committee appends a suggested form of application for registration. Other similar forms could be arranged for the registration of varieties of other crops.

Application for Registration of Varieties of Winter Wheat.

Name desired ....
Origin:
If a hybrid, names of varieties crossed } ....
....
If a pure line, name of the variety
from which selection was made ....
Date of hybridization or selection ....
Name of breeder ..........................P.O.............State..........
Name of applicant ........................P.O.............State..........

Classification:[a]

Superior characters claimed for the new variety, as for example, early maturity, stiffness of straw, yield, bread-making qualities.

....

Number of years tested (refer also to any published results) ....

Manner of making test or tests ....

Number of localities where tested ....

Location of test or tests ....

Yield, as compared with parent stock:

Yield per Acre (Bushels).

	19	19	19	19	Average.
Male parent................					
Female parent................					
Hybrid.....................					
Original variety..............					
Pure line.....................					

Accepted by Committee on Registration of Wheat Varieties and recorded under the name .... and serial number..............this............day of ...., 19...

Secretary of Registration.

---

[a] Sample plants to accompany application.

E. G. Montgomery,
C. G. Williams,
H. K. Hayes,
Committee.

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